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ASTRONOMY. —*Meteors and meteorites.*[1]

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When a shooting star or meteor darts with transient light across the night sky, children may think it is one of the stars of the pattern "come loose"; but the pattern remains as before. The stars of the pattern, which turns daily around the celestial poles, are immense blazing suns, millions of millions of miles away. The meteors are in our atmosphere, less than a hundred miles above the earth; and almost all of them are small, weighing a few pounds or less. When especially bright they are called fireballs. They enter our atmosphere from outside; a very few of them, called meteorites, penetrate to the ground, and provide our only substantial connection with extraterrestrial matter.

METEOR OBSERVATIONS

Among the watchers of the night sky, there have always been some who especially observe meteors, and leaders (like C. P. Olivier, of Philadelphia) who guide them and link them in societies and groups. Other countries, notably England, Russia, and India, also have such watchers.

Even a solitary meteor observer, without a telescope, can do effective work. He learns to know the pattern of the stars and notes where and when, on this background, a meteor appears and disappears, and its brightness—on a scale of magnitudes related to that used for the stars. If two observers, located many miles apart, have thus recorded the flight of a meteor, with sufficient accuracy, its speed, its heights of appearance and disappearance, and the location of its track can be calculated. But only a very small minority of meteors are thus doubly recorded.

Meteors can also be photographed. Sometimes a photograph of part of the sky, taken with a telescope that follows the moving pattern, will show the trail of a meteor that has flashed across during the exposure. A *fixed* camera may record a meteor against a background of circular arcs traced on the plate by the stars of the moving pattern. In these cases the photographs do not indicate the time or location of the meteoric transit. If the same meteor is similarly photographed from a distance of 30 or more miles, the location of path, and the intrinsic brightness of the meteor, can be determined; but without visual timing the speed is not given, unless an occulting shutter on one of the cameras interrupts the exposure a few times each second.

Photographs generally show only very bright meteors, but with a telescope the eye can see meteors of the tenth magnitude or fainter.

THE NUMBERS OF METEORS

On an ordinary clear night a careful observer, without a telescope, will see a first-magnitude meteor about once in each 2-hour interval. He can observe all the bright ones in his field of view, but will miss most of the faint ones; only those near the center of his field of vision will be noticed. From any one place on an average about 50 shooting stars are visible each hour. It is estimated that about 2 million meteors, at least as bright as the first magnitude, fall daily upon the whole earth. Meteor watchers at least have the expectation of having something to record on every clear night. Fletcher Watson, of Harvard, has estimated that nearly

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a billion billion meteors fall daily upon the earth, down to a lower limit of brightness of magnitude 30—far beyond the range of detection by the world's greatest telescope; the existence of a lower limit of brightness is inferred on the basis that smaller objects must have been cleared from the solar system by the sun's radiation pressure.

RANDOM METEORS AND SHOWER METEORS

Besides the isolated meteors that appear from random directions in any part of the sky, there are on some nights *showers* of meteors that are found to diverge from a particular small region of the star pattern, which is called the *radiant* of the shower. The divergence is an effect of perspective; the meteors of a shower really move along nearly parallel trails. Such showers are often called by the name of the constellation from which they radiate—for example, some of the principal showers, coming from the constellations Leo, Perseus, Orion, Gemini, are called the Leonids, Perseids, Orionids, Geminids.

The showers come at definite times each year, though not always with the same abundance; they may last one or more nights in succession. The principal showers are these:

Date of Maximum	*Name*	*Average hourly number*
January 3	Quadrantids	30–40
April 21	Lyrids	7–10
August 10–13	Perseids	40–60
October 20–23	Orionids	10–20
November 16–23	Leonids	10–15
December 11–13	Geminids	60

SUPERSHOWERS

At rare intervals, however, there are supershowers, when meteors rain copiously from the sky, attracting widespread attention. In former times they were often superstitiously regarded as portents of disaster.

There was a great supershower of Leonids in November 1833, when the hourly rate visible may have reached 35,000 at times. It was then that the divergence from a radiant was first recognized by D. Glusted and others. Afterward the American meteor astronomer H. A. Newton collected and discussed the original records of 13 earlier November supershowers, one being as far back as A. D. 902. (The Chinese records of supershowers cover 24 centuries.) He found that they could be fitted to a cycle of recurrence of 33¼ years and that when they appeared they did so in one of the last two or three years of each such cycle. In agreement with his prediction, Leonid supershowers recurred in November 1866, 1867, and 1868.

METEOR SWARMS

The *annual* recurrence of a meteor shower is ascribed to the existence of a cloud or swarm of meteor particles, moving along an orbit intersecting that of the earth. Each year, as the earth traverses the intersection, a meteor shower results if the swarm then extends along that part of its orbit. A periodic *supershower*, like that of the 1833 and 1866 Leonids, indicates that the swarm has a particularly dense part, and that the time of travel round the orbit equals the supershower period. The swarms are, however, very sparse; even at the peak of the 1833 Leonid supershower the meteors must have been about 20 km apart. In ordinary showers their mutual distances must be hundreds of kilometers.

Adams and Leverrier, the independent predicters of Neptune, were stimulated by the 1866 Leonids to calculate their orbit. The long period, 33¼ years, shows that the swarm must travel many times farther from the sun than the earth; and as it comes at least as near to the sun as the earth, its orbit must be a very elongated ellipse, like that of the periodic comets.

METEORS AND COMETS

In 1867 Schiaparelli and Peters, astronomers of Italy and Germany, noticed that the calculated Leonid orbit agreed with that of a comet discovered in 1866, during its passage near the sun. Schiaparelli noticed also that the orbit of the August Perseid meteors agrees with that of another comet, discovered in 1862.

There are now at least six well-established cases of close agreement between orbits of comets and meteor swarms. One such comet, discovered by Biela, has a period of 6.6 years; its orbit was first computed in 1826.

By looking back in the records two earlier appearances were identified. It returned as expected in 1832, but not in 1839; in 1846 it reappeared and then divided into two parts, which gradually separated. They again appeared in 1852, but have not since been seen. However, three periods later, in 1872, when the earth crossed the orbit of the lost comets, there was a meteor supershower, repeated in 1885 after two more periods. This suggested that a meteor stream may result from the disruption of a comet; but this meteor stream, which is called either the Bielid or Andromedid (from its radiant in Andromeda), had given good showers at least seven times before 1872, one as early as 1741. The calculated position of the Biela comets in 1872 was far from the earth. The disruption of Biela's comet was not due to the action of any major planet—none was near it in the period concerned. There is no evidence that the breakup of a comet produces a meteor stream—two or more comets seem a more likely result.

The Leonids have been seen in October or November at least since A. D. 902, the Perseids in August for over 1,200 years, and the Lyrids in April for over 2,500 years; but the associated comets were first observed in the nineteenth century. The nature of the comet and meteor connections is at present mysterious.

In the past 120 years there have been six outstanding supershowers, all associated with cometary orbits; the Leonids in November 1833 and 1866, the Andromedids or Bielids in 1872 and 1885, and the October Draconids in 1933 and 1946. These are also called the Giacobinids because of their association with the Giacobini-Zinner comet; their period also is 6.6 years; the 1946 occurrence was predicted; it was very intense, though brief.

METEOR SPEEDS

When the orbit of a meteor swarm is known, its speed at each point is calculable; hence the meteor speed near the earth is known. The true direction from which they come is not that of their apparent radiant, which is determined by their motion relative to the earth, itself moving along its orbit with a speed of about 30 km per second.

There has been, and still is, some dispute as to the speeds of meteors, but any doubts can only refer to the random nonrecurrent meteors, for which no orbits are known. From visual observations it is difficult to determine the speed of a meteor accurately, and photographic measurements from cameras using a periodic occulting shutter are still few. The main question is whether meteors before falling into the atmosphere are members of the solar system, in which case their speeds relative to the sun, at the earth's distance from the sun, can not exceed 42.1 km per second: or whether they come from outside the solar system, along hyperbolic paths, with greater speed. Recently the radar observation of meteors has added much to our knowledge of meteor speeds and indicates that at least the great majority of meteors do not have hyperbolic speeds.

Relative to the earth, therefore, the speeds can range from 72 km/sec. (for meteors hitting the earth head on) to 12 km/sec. or less (for meteors overtaking the earth).

THE LIGHT FROM A METEOR

What happens when a tiny meteor particle, let us say as big as a pin's head, is swept up by the earth, or drawn down to it by attraction, or maybe overtakes the earth?

It comes into our atmosphere, generally along an inclined path. At first it travels in highly rarefied air but meets ever denser air as it descends. Its impact with the molecules of the air is very violent, owing to its great speed. To the meteor it seems as if the air molecules are rushing on to it with this speed. They slightly penetrate the surface of the meteor, and their great energy of relative motion is communicated to the particle in the form of heat. The surface layer is first melted, and then vaporized; the evaporated meteor atoms spread outward, with small speeds relative to the meteor, but they share its own great speed. Hence they collide violently with the air molecules they meet, mostly not in the direct path of the meteor itself. These collisions break off electrons from the air molecules and the meteor atoms, and also render the meteor atoms luminous; the molecules of the air are less easily ex-

cited to luminosity. Thus the meteor creates around itself, as it moves onward, a luminous cloud of its own atoms; this is what we see as a shooting star, a bright moving point. The cloud is continually blown away, and continually renewed by fresh evaporation until, in the case of small meteors, their substance is exhausted.

METEOR SPECTRA

The spectroscope is able to spread out this meteoric light into a band and reveal what kind of atoms or molecules are emitting the light. But the passage of a meteor is both rapid and unexpected, and their light is relatively faint, so that it is not easy to observe and photograph their spectrum. Only in recent years have detailed reliable results been obtained, notably by P. M. Millman, of Ottawa. They show that the meteoric light is emitted by *metallic atoms*—especially atoms of iron, calcium, magnesium, manganese, chromium, aluminum, nickel, and sodium. Despite much similarity between all his meteor spectra, Millman was able to distinguish two classes, in one of which the lines of ionized calcium are the most prominent feature, whereas in the other they are markedly absent.

All these metallic elements, except sodium, are (as far as we know) practically absent from the air itself. Hence it is inferred that they come from the meteor, and this is confirmed by the analysis of meteorites, namely, the meteors that are large enough to traverse the whole atmosphere and reach the ground. All these atoms are rather easily excited to luminescence by collisions. The light is quite different from that of comets, which show molecular bands in their spectra, and are rendered luminous not by collisions but by the ultraviolet light of the sun.

METEORIC IONIZATION OF THE ATMOSPHERE

As the tiny meteor moves onward surrounded by its small intensely luminous cloud of evaporated atoms, it leaves behind a long trail of electrons and ions, produced by the breakup of atoms and molecules—mostly atmospheric—through violent collisions with the meteor atoms. The electrons and ions recombine soon almost completely, usually in a second or less, but during this time, though so brief, they diffuse outward, enlarging the diameter of the trail, and diminishing the number of electrons per unit volume, or, as we say, the ionization density. The trail will be many miles long, and initially less than an inch in diameter; it may rapidly be distorted by nonuniform winds, or by gusts and turbulence in the air, as we see happens with aeroplane trails at a much lower level.

RADAR OBSERVATION OF METEORS

The ionization trails of meteors have in recent years provided a new means of observing meteors, by radar beams. Free electrons, whether in a metal or a gas, respond readily to the electric alternating field of radio waves and scatter or reflect the waves. The presence of an ionized trail can be detected by a radar beam just as this can detect an airplane or a ship. The trail, during the brief time, usually a fraction of a second, in which its ionization is sufficiently intense, reflects back to their source those radio waves that meet the trail at right angles; waves meeting the trail obliquely are reflected away in other directions. The trail behaves, in fact, like a polished object in the dark, revealed by the glint of a narrow beam of light from an electric torch, from any spot where the beam meets the surface perpendicularly.

The time of passage of the radiowaves, to the trail and back to the receiver, is to be reckoned in microseconds; it gives the distance to the point of reflexion on the trail.

Such observations open a new chapter in meteoric astronomy. They are not hindered by clouds, so that weather need no longer hinder the meteor observer's night watch on the sky. And they are effective by day as well as by night, so that meteors can now be observed whether they fall on the night or the day hemisphere of the earth, although in the latter case their faint luminosity is hidden from us by the daylight glare of the blue sky. Already some important new meteor streams have thus been discovered, which would otherwise have been beyond our knowledge.

To get a sharp radio beam a large aerial is necessary; and to study meteors in different parts of the sky, the aerial must be

movable, like a telescope; this is a difficult instrumental problem, but is being successfully tackled.

Radio beams are more sensitive than the eye, and can detect meteors much fainter than the eye can see. Thus they extend the range as well as the accuracy of meteor observation, to meteors that are extremely small. A bright (first magnitude) meteor is probably less than a millimeter in diameter before entering the atmosphere; the faintest visible to the naked eye is less than a hundredth of an inch.

The beams detect the trail more easily than the meteor itself, but radio methods of determining the speed of the meteor have been developed by C. D. Elyett and J. G. Davies.

METEOR HEIGHTS

The height of appearance and disappearance of a meteor depends on its mass and its speed and also on the vertical distribution of air density in the atmosphere. The smaller meteors disappear at greater heights than the larger meteors, because they are more rapidly evaporated away. There is naturally a range of heights of appearance and disappearance, corresponding to differences of mass, speed, and inclination of the meteors. The heights of appearance range from about 80 to 110 km, with a maximum frequency at about 100 km. But the curve of distribution of the heights of disappearance does not show the simple form that might be expected, but shows two maxima, at about 85 and 95 km, with a minimum in between. In 1922 this was interpreted by F. A. Lindemann and G. M. B. Dobson as indicating that the air at about 60 km height is hotter than that in the lower part of the stratosphere; the basis of the interpretation was a theory of meteor luminosity in the atmosphere. The argument has since had to be revised somewhat, but the conclusion has been confirmed in other ways, most recently by rocket measurements.

METEORS AND UPPER ATMOSPHERIC INVESTIGATION

The investigation of the temperature distribution in the upper atmosphere by means of meteors, begun by Lindemann and Dobson, has been energetically and fruitfully pursued in recent years by the Harvard Observatory and its substations, under the guidance of F. L. Whipple. These studies, like those by means of rockets, are very difficult, and the problems are not yet solved.

Meteors can give other interesting information about the upper atmosphere; occasionally a meteor leaves a *luminous* trail behind it, which may last for seconds, minutes, or even, very rarely, an hour or more. Almost always the trail soon becomes distorted, in a way that shows how far from static is the air at those high levels. The changes of shape indicate nonuniform winds, which may be due to differences of wind at the different heights through which the meteor descends, usually obliquely. In the lower atmosphere such height differences are often made manifest by the different drifts of clouds at different levels. C. P. Olivier has given valuable summaries of the cases of long-enduring meteor trails.

The longest lasting trail known to me is one that appeared on February 22, 1909, and stretched across the English Channel from England to France; the data were very fully discussed by J. E. Clark. The trail was 150 miles long and sloped downward from 55 to 49 miles in height. It remained visible for 1¾ hours. One end rapidly became contorted and dispersed to invisibility, showing strong local turbulence; the rest became greatly bent and curved, revealing winds of speed up to nearly 200 miles an hour, in different directions at different levels.

Many attempts have been made to determine the winds at considerable (though lower) heights by ejecting puffs of smoke from guns or rockets; but it has proved difficult to eject enough smoke to remain visible during the time needed to determine the wind from the drift. Meteors sometimes fulfill the desired purpose for us, at higher levels, but at times and places beyond our control and prediction. Usually these long lasting trails are not observed reliably from different places, as required for the interpretation of their motion in terms of wind. Another observation hitherto lacking for these trails is their spectrum, which would perhaps tell us how a trail can remain luminous for so long. At present this is a mystery.

However, meteors without long-lasting luminous trails can now tell us something about the wind at high levels, by a new radio technique devised by L. V. Manning and O. G. Villard at Stanford. They determine the small change of frequency of the waves reflected by the ionized meteor trail; this is a Doppler effect like the change of pitch of a railway whistle when the train is approaching or receding. It gives the component of the wind along the direction of the radio beam, that is, at right angles to the trail.

METEORITES

The shooting stars so far discussed are those of ordinary brightness, excluding the very bright ones called fireballs; these are larger bodies than the ordinary shooting star, which disappears while still at a great height in the atmosphere, because it becomes completely evaporated.

A much bigger meteor will, like a small one, be heated on the outside by the impact of the air; until it has descended to a height of about 25 miles, its surface layer will be continuously melted and vaporized, but the successive layers removed will form only a small fraction of the whole, and the interior may remain almost at its initial temperature. When it gets to a level where the length of the free paths of the air particles, between collisions, is comparable with the size of the meteor, the interaction with the air changes its character. Instead of the air particles directly striking the meteorite and penetrating it, a cap of compressed air forms in front of it, and a shock wave is set up, as when a bullet flies through the air at a speed greater than that of sound. Less heat is given to the meteorite, whose surface may still be hot enough to be melted, but not to be vaporized. As the meteorite descends to denser air, the molten layer may be blown off in droplets, perhaps seen as a shower of bright sparks scattered along its track. The next layer will then be melted, but below a certain height, as the meteorite gets slowed down, the heat and luminosity may decline, so that the meteorite ceases to shine. Sometimes near the end of its visible track it may break up with a loud detonation, perhaps due to its being in rapid rotation, if its form is irregular. In the last, invisible, part of its track a fireball may be slowed almost to its terminal speed, depending on its shape, size, and weight—a speed maybe comparable to that of sound but far inferior to its initial speed.

Nevertheless this speed may be great enough for the meteorite to bury itself some feet below the ground, leaving a tubular hole behind it.

Meteorites are indeed stones from the sky, and provide our only opportunity, as yet, of directly handling and examining matter not originally part of the earth. Indirectly, of course, astronomers during the past century have been very successful in finding the nature and chemical composition of the celestial bodies by means of the spectroscope.

METEORITES IN THE PAST

In old times, when men readily believed in miracles, the fall of a stone from the sky was easily accepted as a sign from heaven, and if found, it might be regarded as sacred. The image of the goddess Diana of the Ephesians, mentioned in the Acts of the Apostles, where it is said to have fallen from the sky, may have been a meteorite. In Mecca, the Moslem's holy city, there is a sacred black stone in the Kaaba shrine, which from the descriptions of it may well be a meteorite.

A more skeptical temper prevailed in the age of Voltaire and the French Revolution; the learned scientists of the French Academy were not minded to believe in miracles, and they dismissed stories of stones falling from the sky, as fabulous inventions of ignorant people. In 1803 very circumstantial stories reached Paris of a great fall of thousands of stones from the sky at L'Aigle, in Normandy. To put these foolish tales to rest, the Academy charged a distinguished member, Biot, a physicist, to investigate the stories, expecting him to report that they were baseless.

However, Biot listened to the local stories, examined the stones said to have fallen, and reported that they had indeed done so.

FREQUENCY OF METEORITE FALLS

The fall of a sizable meteorite is a rather rare event in any country. Estimates must

be uncertain but have suggested that five or six fall daily on the whole earth, or less than 2,000 a year; and that the average meteorite weighs about 200 pounds before entering the atmosphere but is reduced to about 50 pounds before reaching the ground, by evaporation, successive blowing off of the molten surface layer at lower levels, and breakage. The estimates of the total mass of meteoritic matter annually falling upon the earth vary widely, and range up to more than a million tons, but most of this is in the form of meteoritic dust. The greater part falls into the sea, and claims have been made that meteoritic nickel has been identified in deep sea sediments. Even the highest estimates signify only a negligible accretion of meteoric mass to the earth during its reputed lifetime of the order of a few billion years.

Very few even of the sizable falls are likely to be observed; they descend unseen into the sea or, on land, in lonely and desolate places or among snowy wastes; and many even of those that fall in inhabited countries will fall by day, or from cloudy night skies, and escape notice. Sounds may sometimes be heard, or a fireball seen, or slight tremors may be felt, set up by the impact with the ground; but still the actual fall may not be noticed, or if observed, the stone may not be found.

Meteorites can be grouped in two broad classes, called stony meteorites and iron meteorites. Among meteorites found after being seen to fall, there are more than ten of the stony to one of the iron kind; but in museums, the iron meteorites outnumber the stony ones sixfold. The discrepancy is easily explained: the iron meteorites are much more distinctive, less like terrestrial stones, than the stony ones, especially after weathering has set in. Hence they are often recognizable as meteorites although not seen to fall, whereas the great majority of stony meteorites that fall unseen have remained unrecognized.

METEORITIC FINDS

One record states that up to 1927 the number of falls that were seen, and followed by finds, was 505 (the finds were in some cases made weeks later); and the number of finds not seen to fall was given as 474. These numbers, doubtless incomplete, total nearly 1,000; they refer to *occasions* of falls and finds, whether one stone or many fall at the same time. Some falls yielded thousands of stones, and specimens of them are distributed in museums throughout the world. An outstanding case occurred at Pultusk in Poland in 1868, when perhaps 100,000 stony meteorites fell. Other notable cases occurred at Holbrook in Arizona in 1912, when 14,000 stony meteorites fell; at L'Aigle in Normandy in 1803 (already mentioned), 2,000 to 3,000; and at Stannern in Moravia, 1808, 200 to 300.

The specimens in museums include some recorded falls, mostly modern; the others are the gleanings of millennia.

There is an immense literature on the finding of meteorites and supposed meteorites. Both kinds, iron and stony, are easily distinguishable from any terrestrial stones when carefully examined and still more clearly so when cut across to expose their internal structure. Some big masses fallen ages ago and still on the surface, or partly exposed, or incidentally uncovered, have been recognized by geologists, explorers, and others. Smaller ones have been turned up by the plow, and being noted as unusual have come to be identified by experts.

No meteorites appear to have been found in coal beds or rock quarries. The deepest found was in gold-bearing alluvium, 31 feet down.

VERY BIG METEORITES

The biggest known piece of a meteorite seen to fall weighed 820 pounds, and other pieces were found, from 80 pounds downward; this fell in Arkansas on February 17, 1930. At a height of 10 miles it was seen to break into three pieces; all were lost to view at 5 miles height. The big piece was found 3 weeks later in clay soil; it had made a hole more than 8 feet deep and had scattered clay for 50 yards around. Later a smaller piece was found 2 miles away. All were stony, not iron.

The pieces from some exploded meteorites may be scattered over 100 or more square miles.

The previous biggest meteorite seen to

fall was a stone of 650 pounds in Czechoslovakia, in 1866.

The biggest known meteorites were not seen to fall and may have fallen long ago. The weights range from over 35 tons downward; the biggest is the South African Hoba meteorite, then comes one from Greenland, then a 15- or 20-ton stone at Sinaloa in west Mexico. When Sir John Ross, about 1820, first brought news of the Eskimos of the Cape York region, Greenland, he recorded that they were using meteoritic iron for knife blades, harpoon heads, and other implements. Peary visited the region (Melville Bay) in 1894 and found two large and one smaller iron meteorites, all of which he brought, in two voyages, to New York. The biggest, now in the Hayden Planetarium, New York, is said to measure 12 by 8 by 6 feet and to look like polished steel. The main constituents are iron, 92 percent, and nickel, nearly 8 percent.

THE COMPOSITION OF METEORITES

No terrestrial rocks have such a composition. The stony meteorites also, many of which contain up to 20 or 25 percent of iron (partly metallic, partly oxidized), differ in several respects from terrestrial stones; they may contain also about 20 percent of magnesium oxide; the average silicate content is less than 40 percent, as compared with about 60 percent in terrestrial igneous rocks.

Besides these substances, meteorites, both iron and stony, contain several other elements, pure or oxidized, numbering more than 40 in all. They include for example aluminum, calcium, chromium, manganese, and sodium, already mentioned as contributing to the spectrum of meteors; others such as carbon and hydrogen, though present in meteorites, have not been recorded in meteor spectra. The carbon is sometimes crystalline, like small diamonds, sometimes amorphous like graphite. Some stony meteorites are very hard and will cut glass.

Naturally there are transitional types of meteorites between the stony and the iron, and there is evidence for some exceptional types, one of them being glassy; two cases in which copper, metallic or in combination, was conspicuously present, have lately been discussed by H. H. Nininger and F. A. Paneth.

THE STRUCTURE OF METEORITES

The internal structure of meteorites is very remarkable. The cut surface of an iron meteorite, when etched with acid, shows crystalline markings (known as Widmanstätten figures). Mingled in the iron there are often many crystalline particles of the mineral named olivine, which also occurs on the earth. Stony meteorites contain much olivine, mingled with bits of iron, sometimes apparently introduced therein after the olivine has been shattered. All known meteorites appear to be igneous; that is, heat has played a large part in their evolution, as contrasted with the sedimentary rocks we know, slowly built up by deposition of small particles, water (or air) borne. How meteorites have been formed is still a mystery, and a subject for discussion and controversy. They appear to have undergone repeated disruption and conglomeration, and heating and cooling. Many of them contain remarkable rounded granules called chondrules.

THE RADIOACTIVITY OF METEORITES

The radioactivity and helium content of meteorites has been much studied, in order to infer their age, or the ages of different parts of their conglomerate structure. Iron meteorites, and also some stony meteorites, are able to retain most of the helium resulting from the decomposition of their uranium and thorium. F. A. Paneth, examining separately the metallic and silicate parts of a meteorite that fell at Beddgelert in Wales on September 21, 1949, inferred that the silicate seems to have solidified more than 1,000 million years ago and the metallic part about 200 million years ago (these are preliminary estimates). The ages found for meteorites range very widely, from billions of years down to a million years. Clearly these stones from the sky enshrine much cosmic history which we may hope can gradually be unfolded.

METEORIC SOUNDS AND APPEARANCES

If a meteor no bigger than a pin's head can produce a bright shooting star, meteor-

ites large enough to reach the ground, in one or more sizable pieces, may be expected to be much more conspicuous in their falls. Even the Beddgelert meteorite just mentioned, that weighed a little under 2 pounds, though probably only part of a larger body, was reported as making a noise like an express train or fast airplane. Many meteorites break up with great explosive sounds. Intense brightness, of different colours (in different cases), is a common feature, though in the few cases of visible daylight meteors the light is relatively dimmed; in such cases a smoky trail may be left after the passage of the meteorite.

LEGAL AND FINANCIAL ASPECTS

The Beddgelert meteorite was found on the top floor of a hotel, having cleanly penetrated the roof. To whom does a meteorite belong that falls thus in a building or on private land? The law differs from country to country, and in England the question has never been determined; the Beddgelert meteorite was only the ninth meteorite seen to fall, and then found, in the history of England and Wales. In this and earlier cases the stone was disposed of by agreement; the Beddgelert hotel keeper sold the stone to the British Museum and the University of Durham jointly; his landlords, a public company, laid no claim to it.

Meteorites may raise legal and financial problems in other ways; for example, was the insurance company liable to pay for the damage caused to the roof? There is no space here to enlarge on these matters, except to say that from scientists and museums there is a considerable demand for meteorites, which may command up to 500 or even 1,000 dollars per pound.

Damage to property and persons by meteorites is rare. The nineteenth-century French astronomer Flammarion said in one of his books (1872) that meteorites had caused 14 fatalities but did not cite his authorities. In 1906 there were newspaper reports of a Mexican sheep herder in Texas being killed by a meteorite, but I do not know whether the report was true.

METEOR CRATERS

Now I come to the last phase of this cursory survey of a wide-ranging subject—the hole made by a great meteorite when it meets the ground.

The deepest *tubular* hole found was about 8 feet long; usually it is less. One of the many fragments of a meteorite that fell in Rhodesia on October 5, 1950, broke a log in two and buried itself 4 feet down.

There is, however, a quite different kind of hole made by meteorites of the greatest mass and momentum, which remain unbroken during their flight, or, if broken, not too dispersed. Holes of this second kind are called craters; they might well form the subject of a whole lecture, and more.

Fourteen crater regions are now known, counting only craters of 100 feet diameter or more; in some regions the craters are not single but in groups of 20, 50, or even more.

The most famous crater is that of Arizona, near Flagstaff. Alaska has one on Amak Island, discovered in 1942. The United States has yet a third crater, in Texas. Australia has four known craters or groups of craters, Canada one, Argentine one, Africa one, Europe one, Arabia one, and Siberia two. Most of the craters are prehistoric, but those of Siberia were formed in living memory in 1908 and 1947.

The conversion of the immense kinetic energy of the meteorites in these cases must involve enormous generation of heat and explosive force, but seems not to cause deep penetration.

I will close with a brief account of the greater of the Siberian falls, of 1908. It occurred in a desolate region consisting of wooded shallow swamps overlying permafrost. An observer at a distance saw in the early morning hours of June 30 a fiery body rising from the southern horizon, like a small sun, which hurried northward. Less than a minute later the ground around him suddenly rose and fell again—a harmless earthquake shock. Then a pillar of fire mounted up in the sky, and at once three or four distinct blows of incomparable force and quality were heard, followed by a roar and rumbling. This was audible over an area more than 600 miles in radius. River waters rose in big waves, animals were blown off their feet, many buildings were damaged; all this was far away from the fall. An atmos-

pheric wave was set up that traveled twice round the globe.

At dusk the same day enormous silver clouds were seen, at more than 50 miles height; they scattered the light of the sun after sunset, and almost turned night into day over much of Siberia. Some days later there were several remarkably light nights over England, whither some of the high dust had drifted. Their cause, and that of the barometric disturbances, was not discovered till many years had elapsed.

Near the impact two villages disappeared, and all the trees were overturned within a radius of many miles. They were so seen when Russian scientists first visited the place 18 years later. But in the center of the region there was no great crater like that of Arizona, which is nearly a mile across. There were also many large water-filled holes, the biggest of them 150 feet across.

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BOTANY.—*A new* Guzmania *from Colombia*. LYMAN B. SMITH, Department of Botany, U. S. National Museum.

The following species of bromeliad is one of a large number of novelties discovered in Colombia by Mulford B. Foster. Its separate treatment here is made necessary by its presence in another collection which is due to be reported sooner than the remaining Foster novelties.

Guzmania geniculata L. B. Smith, sp. nov.
Fig. 1

Verisimiliter acaulis; laminis foliorum ligulatis, subglabris; scapo erecto; scapi bracteis imbricatis; inflorescentia bipinnata, basi laxa; axi geniculato; bracteis primariis spicas inferiores subaequantibus; bracteis florigeris quam sepalis paulo brevioribus, laevibus; sepalis breviter connatis.

Probably stemless, the flowering plant 8 dm high; leaves 7 dm long, the sheaths about 1 dm long, dark castaneous at the base, purple-striped above, appressed-lepidote, the blades ligulate, acute, 4 cm wide or more, very obscurely lepidote, green; scape erect, stout; scape-bracts strict, imbricate, the lower foliaceous, the upper ovate, acute; inflorescence cylindric, bipinnate, lax below, dense near the apex; axis geniculate, stout, dark castaneous in age; primary bracts ovate, acute, the lower ones about equaling the spikes, the upper much shorter; spikes divergent, dense, subglobose, 3 cm long, the stipe stout, flattened,

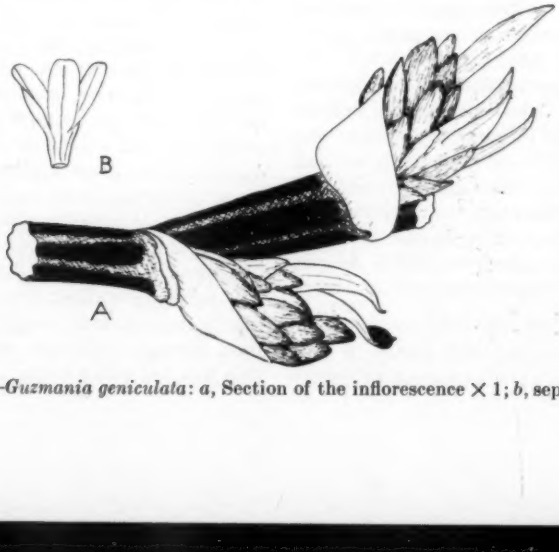

FIG. 1.—*Guzmania geniculata*: *a*, Section of the inflorescence × 1; *b*, sepals × 1.

5–10 mm long; floral bracts broadly ovate, rounded with a thick apical cusp, slightly shorter than the sepals, coriaceous, even, glabrous, castaneous in age; flowers subsessile; sepals elliptic, 13 mm long, connate for 3 mm, nerved; petals and stamens unknown.

Type in the Gray Herbarium, collected on trees, above Sibundoy, Territory of Putumayo, Colombia, altitude 2,280 meters, October 28, 1946, by M. B. and R. Foster (no. 1972).

Its stout geniculate floral axis distinguishes *Guzmania geniculata* from the group of species around *G. sphaeroidea* (André) André ex Mez where it shows its closest affinity.

ENTOMOLOGY.—*A review of the genus* Tegenaria *in North America (Arachnida: Agelenidae).*[1] VINCENT D. ROTH, Oregon State College. (Communicated by C. W. Sabrosky.)

This review is not intended to be a complete taxonomic discussion of the Nearctic *Tegenaria* but aims to clarify the position of the many names used in this genus. The area under consideration is that part of North America north of and including Mexico. This study was stimulated by Roewer's *Katalog der Araneae*, in which he lists 16 species of *Tegenaria* from the Nearctic region. Since its publication, one more species has been added. Of the total, five are recognized as valid, three are questionable species, one probably does not belong to the Agelenidae, four are placed in synonymy, and four are true calymmarids.

Keys and notes are furnished for the separation of the recognized species, and the remaining species are discussed briefly. The female epigynum for two of the species is illustrated for the first time.

The species of North American *Tegenaria* are identified by the following characteristics: size moderate to long, varying from 6 to 17 mm in length; color usually tan to brown with darker markings; integument of carapace, legs, and abdomen densely to sparsely covered with white to brown plumose hair; carapace similar in shape to other Ageleneae, pars cephalica narrowed to about one-half the width of the pars thoracica; eyes similar in size; chelicerae slightly to strongly geniculate, promargin bears 3 to 6 teeth, the retromargin 3 to 6 teeth and none to 2 or 3 denticles; legs moderately long with scattered spines; spinnerets subapical in position; anterior and posterior spinnerets widely separated, the latter situated laterally and slightly dorsally to the median spinnerets; distal segment of the anterior spinnerets small, hemispherically shaped; median spinnerets almost as long as anterior spinnerets; basal segment of posterior spinnerets as long as anterior spinnerets, distal segment as long as the basal segment, slender and tapering distally. The following key will separate the *Tegenaria* from other North American Agelenidae:

1. Plumose hair present on carapace, abdomen, and legs (visible with 30–100 × magnification). (The hairs are often scarce on specimens that have been shaken about in alcohol for many years.).....(AGELENEAE)....2
   Plumose hair absent on carapace and abdomen; hair either setose or barbed (*Cybaeota*)
   other AGELENIDAE
2. Anterior eye row almost straight; anterior median eyes located between the anterior lateral eyes.....*Tegenaria*
   Anterior eye row strongly procurved; anterior median eyes located, more or less, between the posterior lateral eyes..other AGELENEAE

The following key to the species of North American *Tegenaria* is adaptable to both immature and adult spiders:

1. Promargin of chelicera with 3 teeth.....2
   Promargin of chelicera with 4 to 6 teeth, oc-

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Unless otherwise indicated all specimens have been collected by and are in the collection of the author. Abbreviations used with distributional records are: USNM, United States National Museum; AM, American Museum of Natural History; CAS, California Academy of Sciences; and HEF, the collection of Mrs. D. L. (Harriet Exline) Frizzell, of Rolla, Mo.

The author expresses his thanks to Dr. W. J. Gertsch, of the American Museum of Natural History, Dr. E. A. Chapin and Dr. W. D. Field, of the U. S. National Museum, and Mrs. Frizzell, all of whom generously supplied material and information. In addition many thanks are extended to Miss E. B. Bryant, of the Museum of Comparative Zoology, and E. Browning, of the British Museum (Natural History), for information concerning certain types.

casionally 3 on one side but never on both sides.....4

2. Retromargin with 3 or 4 teeth and no denticles (cosmopolitan).....*domestica* (Clerck)
Retromargin with 4 to 6 teeth and 2 or 3 denticles.....3

3. Sternum with 3 or occasionally 2 pairs of distinct, round, light spots laterally; conductor of male palpus ending with a single spur; epigynum bearing 2 broad lateral spurs (Pacific Northwest).
gigantea Chamberlin and Ivie <fl.
Sternum usually lacking paired light round spots, if present, indistinct; conductor of male palpus terminated by 2 long pointed teeth; epigynum lacking lateral spurs (Pacific Northwest, Europe).
agrestis (Walckenaer) <fe

4. Sternum with two pair of light round spots laterally and a median mark which is tridentate posteriorly (southern U. S. from California to Alabama).....*antrias* Crosby
Sternum lacking paired, light round spots (southern Mexico).*flexuosa* O. P. Cambridge

RECOGNIZED NORTH AMERICAN SPECIES OF TEGENARIA

Tegenaria agrestis (Walckenaer)

Aranea agrestis Walckenaer, 1802: 216 (♂ ♀).
Tegenaria magnacava Exline, 1936: 23, fig. 5 (♀).
Tegenaria magnacava Exline, Chamberlin and Ivie, 1937: 213 (synonymy suggested at this time).
Tegenaria agrestis Walckenaer, Exline 1951: 308–310, figs. 1–5 (♂ ♀).
For complete synonymy and references consult Roewer, 1944: 24.

Color: Sternum yellowish orange, with two dusky markings extending from the lateral edges of the labium, posteriorly to opposite the third coxae where the lines fade out. On immature specimens the dusky markings are darker, outlining three pairs of light, round spots laterally and a median light line. Legs lack dusky annulations.

Chelicera: Promargin armed with 3 teeth; retromargin bearing 4 or 5 teeth and 2 or 3 denticles.

Size: Males (2) 9.5 and 10.3 mm; female (1) 12.7 mm.

Distribution: Europe. Seattle, Wash. OREGON: Corvallis, Aug. 29, 1947 (♂ ♀), May 18, 1949 (imm.), April 16, 1951 (imm.).

Type locality: The female holotype of *T. magnacava* Exline from Seattle, Wash., has been placed in the Museum of Comparative Zoology at Harvard University. The type locality of *T. agrestis* Walckenaer was probably France. The original description was not available to author.

Tegenaria antrias Crosby

Tegenaria antrias Crosby, 1926: 2, fig. 3 (♀).
Tegenaria simplex Bryant, 1936: 90, fig. 9 (♀) (n. syn.).
Tegenaria castro Chamberlin and Ivie, 1942: 21, figs. 27–29 (♂ ♀) (n. syn.).

The author has had on hand males and females from the type localities of *T. antrias* Crosby and *T. simplex* Bryant, and a female from the type locality of *T. castro* Chamberlin and Ivie. There are no significant differences in structure or color, only the minor variations one finds in long series. Miss Bryant graciously compared the type of *T. simplex* Bryant with specimens from the three type localities and declared them identical.

Color: Sternum dusky with a median light band, trifurcate on the posterior half. Anterior portion flanked by two light spots on either side. Legs with dusky annulations, darkest on legs IV, becoming lighter on the anterior legs, indistinct on legs I.

Chelicera: Promargin armed with 4 teeth, occasionally 3 or 5 on one side. Retromargin with 3 to 5 teeth, the mesal two teeth often fused at base.

Size: Males (7) range in size from 5.5 to 10.1 mm, averaging 7.5 mm; females (15) 5.3 to 10 mm, averaging 7.2 mm.

Distribution: Southern United States from Alabama to California and north to Sacramento, Calif. It is also probably present in northern Mexico. NEW MEXICO: Carlsbad Caves, 1941, no other data (♂ ♀), USNM; CALIFORNIA: Sacramento, May 27, 1918, H. Van Duzee (2 ♀), CAS; San Francisco, R. F. Sternitsky (3 ♀), AM; Castro Valley, Alameda County, Sept. 16, 1938, W. M. Pearce (3 ♀), AM; Nov. 11, 1938, W. M. Pearce (♀), Feb. 26, 1939, W. M. Pearce (imm.), AM; TEXAS: 3–4 miles west of Dallas, 1935–37, Ottys Sanders (♀), AM; Austin, Nov. 25, 1945, D. L. and H. E. Frizzell (2 ♂, 7 ♀), HEF, April 27, 1946, D. L. and H. E. Frizzell (3 ♀), HEF; ALABAMA: Mobile, 1941, Archer (♂ ♀), AM. In addition one specimen (♀) labeled "Altoona, Pennsylvania" is in the collection at the United States National Museum. This is undoubtedly mislabeled.

Type locality: Female type of *Tegenaria antrias* Crosby from Carlsbad Caves, N. Mex. This type is supposedly deposited in the United States National Museum, but the author was unable to locate it during a visit in the summer of 1950. Female holotype of *T. simplex* Bryant from Dallas, Tex., is deposited in the Museum of

Comparative Zoology at Harvard University. The female holotype of *T. castro* Chamberlin and Ivie from Castro Valley, Alameda County, Calif., male allotype from Lindsay, Okla., both in the University of Utah collection.

Tegenaria domestica (Clerck)

Araneus domesticus Clerck, 1757: 76, fig. 9 (♀).
Tegenaria detestabilis O. P. Cambridge, 1877: 275 (♀) (n. syn.).
T. derhami Scopoli, Exline, 1938: 24–25, figs. 25–26 (♂♀).
T. derhamii Scopoli, Kaston, 1948: 279–280, figs. 895–899, 2053–2055 (♂♀).
For complete synonymy and references consult Roewer, 1944: 31.

T. detestabilis O. P. Cambridge was described from one female which, "had been damaged by an attempt at preservation in turpentine, whereby the eyes were concealed . . . For the same reason the exact form of the genital aperture was scarcely plain." At the request of the author, E. Browning, of the British Museum, graciously cleaned the type and forwarded an exceptionally clear illustration of the external epigynum which compares favorably with that of *T. domestica* (Clerck).

Color: Sternum varies from a yellowish brown with no markings to a dark brown with a pale median line flanked with two or three pale spots. Legs variable, usually with dusky annulations, occasionally without.

Chelicera: Promargin armed with 3 teeth, retromargin usually armed with 4 teeth, occasionally 3.

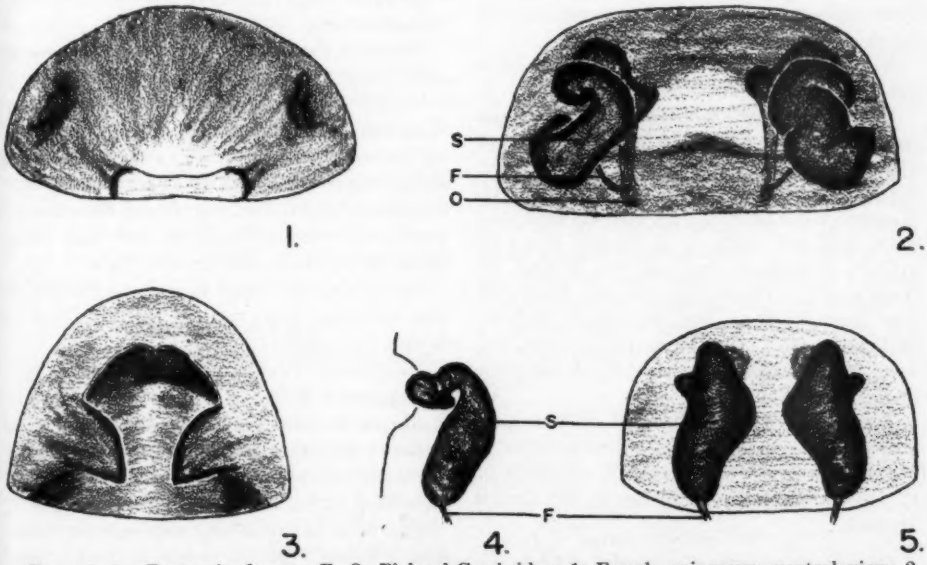
Size: Males (9) range in size from 6.1 to 8.5 mm, averaging 6.84 mm; females (11) 6.3 to 8.9 mm, averaging 7.53 mm.

Distribution: Cosmopolitan. In the area considered in this paper, *T. domestica* (Clerck) has been collected from northern Canada (lat. 79° N., long. 74° W. on the east coast of Ellesmere Island, the type locality of *T. detestabilis* O. P. Cambridge) to southern Mexico (Uruapan, Michoacán, September 17, 1943, M. Cárdenas (♂), AM) and from the Pacific to the Atlantic coasts.

Tegenaria flexuosa F. O. Pickard-Cambridge
Figs. 1, 2

Tegenaria flexuosa F. O. Pickard-Cambridge, 1897–1905: 334, figs. 34–34a. (♂).

T. flexuosa F. O. Pickard-Cambridge was described from a single male and two immature females from Omilteme in Guerrero, Mexico. Several mature females from southern Mexico were studied for the present review.



FIGS. 1, 2.—*Tegenaria flexuosa* F. O. Pickard-Cambridge: 1, Female epigynum, ventral view; 2, female epigynum (cleared) dorsal view. (S, spermatheca; F, fertilization duct; O, opening of the epigynum.)

FIGS. 3–5.—*Tegenaria gigantea* Chamberlin and Ivie: 3, Female epigynum, ventral view; 4, lateral view of spermatheca; 5, female epigynum (cleared), dorsal view. (S, spermatheca; F, fertilization duct.)

Color: Sternum dark brown with a light-brown rectangular mark extending from the base of the labium to the middle of the sternum where it narrows to form a slender, light mark to the posterior edge. Median mark absent in the lighter colored specimens. Legs with dusky annulations which become lighter distally. They are darkest on the first pair of legs, becoming successively lighter on the posterior pairs.

Chelicera: Promargin of chelicera armed with 4 teeth, retromargin armed with 5 or 6 teeth and 2 or 3 denticles.

Epigynum: The external epigynum is quite simple and lacks heavy sclerotization as is usually present in *Tegenaria*. The most evident structure is a transverse subrectangular median sclerite, in front of which is a whitish, membranous area. Barely visible through the integument are parts of the spermathecae lying at a 45° angle from the lateral anterior edges of the median sclerite.

The internal epigynum consists of two separate halves. One side is herewith described. The transparent connecting canal arises along the lateral edge of the median sclerite and extends dorsally to the spermatheca. The latter consists of a heavily sclerotized tube, strongly twisted, and folded back upon itself at two points as illustrated in figure 2. A slender fertilization duct arises posteriorly along the mesal edge of the spermatheca and curves dorsally.

Size: Male (type) 7 mm; females (3) range in size from 7 to 9.8 mm.

Distribution: All recorded specimens and specimens seen by the author have been collected within a 180-mile radius from Mexico City, Mexico. MORELOS, Cuernavaca, Sept. 1941, H. Wagner (♀), AM; SAN LUIS POTOSÍ, Tamazunchale, July 6–7, 1941, L. I. Davis (♀), AM; MÉXICO, Tenaningo, Sept. 27–Oct. 7, 1946, H. Wagner (♀); GUERRERO, Parque Humboldt near Taxco, 2,500 m., Dec. 26, 1943, C. Bolívar, C. Tellez (imm.), AM; FEDERAL DISTRICT, Desierto de los Leones, Mar. 12, 1944, M. Cárdenas (imm.) AM.

Type locality: A male type and two immature females were collected at Omilteme, Guerrero, in Mexico and are deposited in the collection of F. D. Godman and O. Salvin at the British Museum.

Tegenaria gigantea Chamberlin and Ivie

Figs. 3–5

Tegenaria gigantea Chamberlin and Ivie, 1935: 31, fig. 106 (♂).

T. gigantea Chamberlin and Ivie, Exline, 1936: 21, fig. 3 (♂).

T. gigantea Chamberlin and Ivie, Exline, 1938: 25, figs. 30–31 (♂).

Color: Sternum dark brown with a pale median stripe arising at base of labium, expanding slightly and then narrowing posteriorly. Three pale spots lie laterally to the median line. Occasionally the posterior spot nearly connects with the median line forming a tridentate mark. Legs lack annulations. Male femur in this species often a very dark brown, contrasting with the yellowish brown of the other legs.

Chelicera: Promargin armed with 3 teeth; retromargin teeth variable, usually 5 or 6 teeth, occasionally 4 and 2 or 3 denticles.

Epigynum: The female of *T. gigantea* Chamberlin and Ivie was never described or illustrated, although female paratypes were designated. The following description of the epigynum was taken from females collected at the type locality.

The external epigynum consists of an irregular, convex median sclerite widened posteriorly. At each of the lateral edges is a depression and the opening of the spermathecae. Two broad, flat spurs extend over the lateral edges of the median sclerite toward the median line. The dull points of the spurs end at the three-quarter mark from the anterior end of the median sclerite.

Internally the strongly sclerotized epigynum is quite simple and slightly asymmetrical. One half is herewith described. The spermatheca consists of an irregular tube lying longitudinally and curving ventrally at the external opening where it is slightly constricted. The distal portion between the opening and the main portion of the spermatheca is bulbous and bears a short and blunt lateral projection as illustrated in Fig. 4.

Size: Males (12) range in size from 9.1 to 15 mm, averaging 12.02 mm; females (10) 11.8 to 17 mm, averaging 13.93 mm.

Distribution: Found only on the southern half of Vancouver Island, British Columbia. Many males and females from "Vancouver Island" collected by R. Guppy from May to October are in the American Museum of Natural History in New York City.

The male holotype was collected on "Vancouver Island," British Columbia, female allotype at Sidney, a small town 14 miles north of Victoria, British Columbia. Both types are deposited in the University of Utah.

STATUS OF OTHER "TEGENARIA" LISTED IN ROEWER'S "KATALOG DER ARANEAE"

Tegenaria arboricole Walckenaer

Abbot, 1792: 12, figs. 109, 110.
Tegenaria arboricole Walckenaer, 1841: 6 (♂). Fig. 110 of Abbot's.
T. nemorensis Walckenaer, 1841: 10–11 (in part, variety 2) (♀). Fig. 109 of Abbot's.
T. arboricole Walckenaer, Chamberlin and Ivie, 1944: 128–129.

Chamberlin and Ivie (1944: 128–129) state, "It (Abbot's figure) is undoubtedly an Agelenid, but we are not certain of the genus so leave it in *Tegenaria* for the present."

Type locality: Georgia. Abbot's figure 110 was used as the basis for the description of *T. arboricole* Walckenaer. There apparently was no specimen on hand at the time the description was drawn up.

Tegenaria flavens Hentz

Tegenaria? flavens Hentz, 1847: 464, fig. 22 (♀).

After studying the illustration of *T. flavens* Hentz Dr. W. J. Gertsch stated, through correspondence, "*Tegenaria flavens* does not belong to the genus and probably not even to the family." The author is inclined to agree with him.

Type locality: Alabama. The type has apparently been lost.

Tegenaria nemorensis Walckenaer

See *T. arboricole* Walckenaer and *Coras medicinalis* (Hentz).

Type locality: "Georgia." Abbot's figures 107 to 109 were used as the basis for the description of *T. nemorensis* Walckenaer. There were apparently no specimens on hand at the time of the description.

Tegenaria obscura Banks

Tegenaria obscura Banks, 1898: 230–231, fig. 26 (♀).

Tegenaria obscura Banks was described from a single female from "San Miguel de Horcasitas." This is probably the river which is now named Río de San Miguel, whose headwaters are about 28 miles southeast of Nogales, Ariz., in Mexico. The type was deposited in the California Academy of Sciences and was apparently lost during the San Francisco fire and earthquake of 1906. This species is close to and probably identical with *T. antrias* Crosby which has been collected in the southwestern part of the United States.

Tegenaria praegrandis Fox

Tegenaria praegrandis Fox, 1937: 176–177, fig. 3 (♀).

Tegenaria praegrandis Fox was described from a single female from "Washington D. C. Dept. Grounds, Hothouse, outside" (Marx's catalog). A species as large as this (13.96 mm) and with the conspicuous habits of the genus would surely be collected again in 56 years. (No date was given, but Marx died in 1895.) In view of this and the fact that Marx's locality labels have often been found to be inaccurate, the author is including this species under the "unrecognized *Tegenaria*." The female is close to *T. gigantea* Chamberlin and Ivie but the genitalia are definitely different. It will probably prove to be an exotic species.

The type (no. 1255) is deposited in the United States National Museum at Washington D. C.

Calymmaria cavicola (Banks)

Tegenaria cavicola Banks, 1896: 202–203 (imm.).
Calymmaria cavicola Banks, Chamberlin and Ivie, 1937: 213.
Tegenaria cavicola Banks, Roewer, 1944: 33.
Calymmaria cavicola Banks, Muma, 1945: 95.

Calymmaria modestella (Roewer)

Tegenaria modesta Banks, 1898: 230, fig. 21 (♀). (Preoccupied by Keyserling 1877.)
Calymmaria modesta Banks, Chamberlin and Ivie, 1937: 213.
Tegenaria modestella Roewer, 1944: 33 (new name).

Calymmaria persica (Hentz)

Tegenaria persica Hentz, 1847: 463, fig. 23 (♀).
T. persica Hentz, Roewer, 1944: 33.

The type of *T. persica* Hentz has apparently been lost but the illustration given by Hentz indicated the probable genus. Dr. W. J. Gertsch states through correspondence, "*Tegenaria persica* Hentz is very clearly a *Calymmaria* and a species occurs in Alabama (the type locality of *T. persica* Hentz) which I have not been able to differentiate from (*Calymmaria*) *cavicola* Banks."

Calymmaria quadrata (Exline)

Tegenaria quadrata Exline, 1936: 22, fig. 4 (♀).
Calymmaria quadrata Exline, Chamberlin and Ivie, 1937: 213.
Tegenaria quadrata Exline, Roewer, 1944: 33.

Coras medicinalis (Hentz)

Abbot, 1792: 12, figs. 107–108 (♂♀).
Tegenaria medicinalis Hentz, 1821: 53, figs. 1a, 1b.
Tegenaria nemorensis Walckenaer, 1841: 10–11 (in part, varieties 1 and 3) (♂♀). Figs. 107–108 of Abbot's.

Coras medicinalis Hentz, Chamberlin and Ivie 1944: 129.
Coras medicinalis Hentz, Roewer, 1944: 20.
Tegenaria nemorensis Walckenaer, Roewer, 1944: 33.
Coras medicinalis Hentz, Muma, 1946: 4–5, figs. 1–3, 21–24 (♂ ♀).
Coras medicinalis Hentz, Kaston. 1948: 281–282, figs. 900–902, 1914–1915 (♂ ♀).
See Roewer, 1944: 20 for additional synonymy.

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ENTOMOLOGY.—Johnsonaepsylla audyi, *a new genus and new species of flea from North Borneo, with notes on the subfamily Leptopsyllinae (Siphonaptera).*[1]

ROBERT TRAUB, Lt. Col., M.S.C., Army Medical Service Graduate School, Washington, D. C.

In connection with studies on the epidemiology of scrub typhus and leptospirosis, a joint U. S. Army–British Colonial Office Medical Research Team operated in North Borneo in July and August 1951. During the course of these investigations, fleas, mites, and other ectoparasites were collected from small mammals, particularly on Mount Kinabalu. Among the material represented in the valuable collections is the unusual flea herein described as a new genus and new species of the family Ceratophyllidae, subfamily Leptopsyllinae. Fleas of this subfamily are frequently true parasites of *Rattus*, as well as of *Mus* and other mice, and hence are of potential medical significance.

A discussion of the subfamily Leptopsyllinae is included in this paper because of recorded differences of opinion as to the systematic position of this important group of fleas and because the new genus makes necessary a reevaluation of the diagnostic characters of the subfamily. This genus also indicates relationship between the Leptopsyllinae and the Amphipsyllinae.

[1] Published under the auspices of the Surgeon General, Department of the Army, who does not necessarily assume responsibility for the professional opinions expressed by the author.

Family CERATOPHYLLIDAE

Subfamily LEPTOPSYLLINAE

Johnsonaepsylla, n. gen.

The only leptopsylline flea which lacks a genal ctenidium or which has five pairs of lateral plantar bristles. Agrees with *Paractenopsyllus* Wagner, 1938, and *Peromyscopsylla* I. Fox, 1939, in the absence of a dark tuber above upper margin of the antennal groove in vicinity of the characteristic pale ring (Fig. 1, *RG.*). Agrees with *Paractenopsyllus* Wagner, 1938, in that the anterior portion of the head is normal in shape, not conical as in other leptopsyllines. Caput fractum. Eye distinct but somewhat reduced. Preantennal region with three rows of bristles, some of first row submarginal and somewhat spiniform. Frontal tubercle distinct. Postantennal area with three rows of bristles. Antennal segment 2 with bristles short; in male, not reaching beyond proximal fourth of club. Antennal groove not extending onto propleuron. Labial palpi much shorter than forecoxae. First vinculum or link-plate (*VC.1*) received in distinct sinus of prosternosome. Pronotal comb consisting of narrow spines. Pronotum with one row of long bristles. Some of dorsolateral bristles of protibiae short and straight, forming a reduced comb; these bristles on mesotibiae and metatibiae smaller, so that comb is vestigial (unlike other fleas in subfamily). Procoxae with many lateral bristles scattered over length of segment; other coxae with very few bristles and these on anteroventral margin. Profemora with very few lateral and mesal bristles. Mesosternum (Fig. 7, *MST.*) apparently enlarged so that metasternum appears as if divided into dorsal and ventral regions by an oblique sclerotization. Lateral metanotal area (*L.M.*) distinct. Pleural region of metasternosome fitting into well-sclerotized socket, the pleural arch (*PL.A.*). Metanotum and some of typical abdominal terga with apical spinelets. Unmodified terga usually with two rows of bristles, but first row reduced, or absent on some. Spiracles subovate. Male with three antepygidial bristles. Eighth tergum fairly well developed, extending as far caudad as middle of immovable clasper. Eighth sternum (Fig. 4, *8S.*) relatively large and unmodified. Digitoid (*F.*) with stout bristles but no spiniforms. Apical appendage of aedeagus (*AP.A.*) very well developed. Sclerotized inner tube (Fig. 9, *S.I.T.*) oblique and relatively unarmed, with distinct apicomedian sclerite (*A.M.S.*). Crochets (*CR.*) very large and conspicuous. Distal arm of ninth sternum narrow and sinuate; without spiniforms.

The female of this genus is unknown.

Genotype: *Johnsonaepsylla audyi*, n.sp.

The genus is named for Miss Phyllis Johnson, of the Department of Entomology, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C., one of the most promising students of medical entomology and to whom I am much indebted.

Johnsonaepsylla audyi, n. sp.

Types.—Holotype male *ex Hylomys suillus* Muller, a small spineless hedgehog (Insectivora, Erinaceidae); North Borneo, Mount Kinabalu, elevation 5,000 feet, Tenompak; July 16, 1951; collected by R. Traub. Two paratype males with same data but from two other *Hylomys suillus*. A fourth paratype male, ibid., but at Lumu Lumu, elevation 6,300 feet, in the cloud forest; July 21, 1951. Holotype deposited in the collections of the United States National Museum. Paratypes deposited in the Chicago Natural History Museum, the British Museum (Tring), and the author's collection.

Head (Fig. 1).—Preantennal region with bristles as follows: First row of six, ventral four of which are stout and more or less spiniform, particularly the upper two at level of frontal tubercle; second row of two large bristles, ventralmost submarginal; third row of two long bristles, uppermost at or somewhat above level of eye. Anterior arm of tentorium (*T.A.*) visible on each side as a rodlike structure anterior to eye. Eye subovate, small. Genal process subacute. Maxillary lobe with anterior wing weakly sclerotized but distinct, arising anterior to base of maxillary palpi. The more heavily sclerotized portion (that area usually depicted in drawings of maxillary lobes of most fleas) originating definitely posterior to these palpi. Apex of maxillary lobe extending distad of base of fourth segment of maxillary palpi. Labial palpi 5-segmented, extending three-fourths length of forecoxae. Scape of antenna with about three short dorsomarginal subapical bristles. Second antennal segment with apical bristles short, not reaching beyond apex of third segment of club. Postantennal region with rows of bristles arranged 3–4 (5)–6 per side, ventralmost of last row displaced to ventrocaudal angle; at

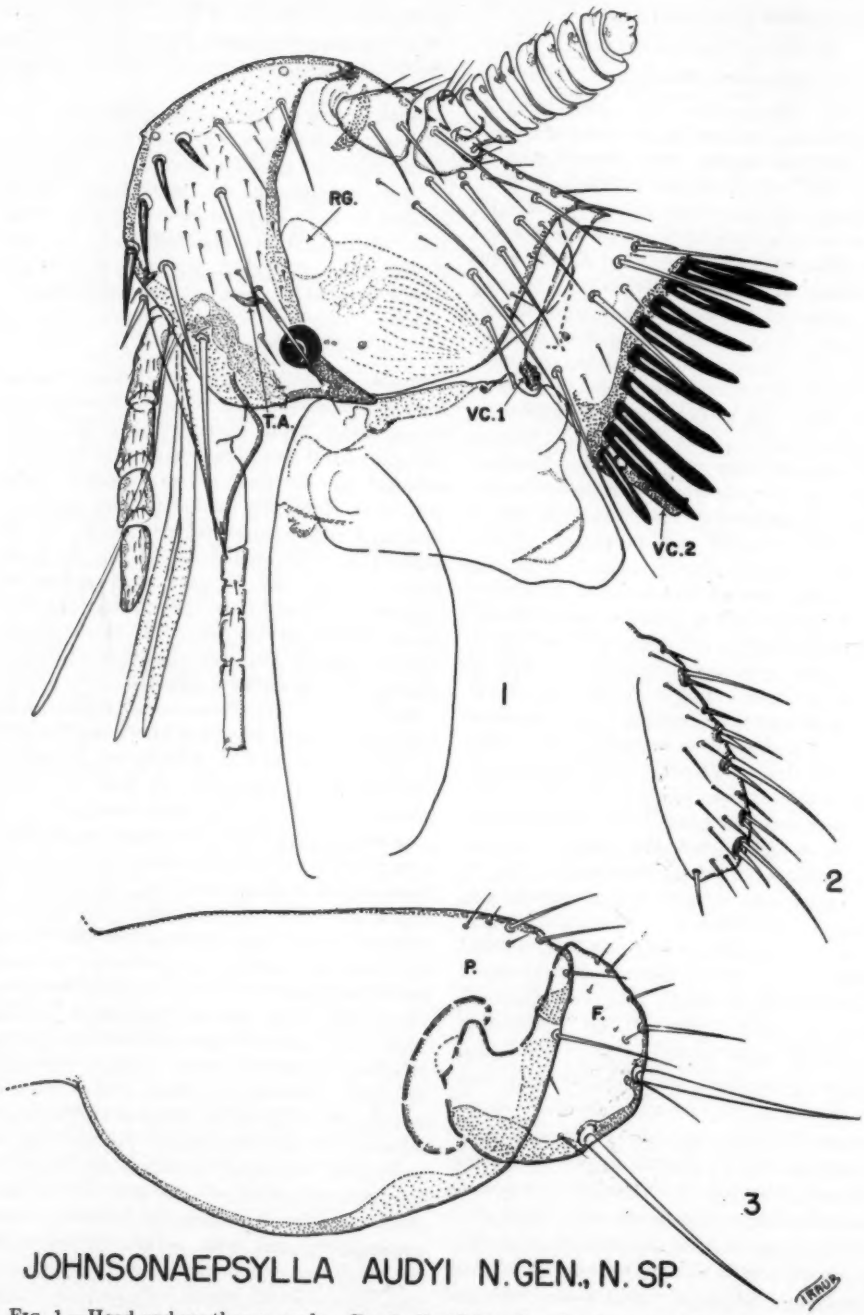


FIG. 1.—Head and prothorax, male. FIG 2—Protibia. FIG. 3.—Immovable process of clasper and digitoid.

times with an additional dorsomarginal bristle at base of flange; intercalaries displaced caudad along margin of flange. First vinculum or link plate (*VC.1.*) somewhat irregular in shape, at times subpyriform.

Thorax.—Pronotum with a row of four or five long bristles; small intercalaries displaced caudad; with a comb of about 10 or 11 spines on a side; the spines straight or slightly concave. Second vinculum (*VC.2.*) almost completely concealed by lower spines of pronotal comb; very broad at base, apex upcurved where it hooks onto mesepisternum. Mesonotum (Fig. 7, *MSN.*) with about four rows of bristles, first row of shortest bristles, those of last row longest, about four in number; ventralmost arising above midpoint of notum. Mesonotal flange on each side with a subdorsal pseudoseta (*PS.S.*). Mesopleuron with a total of about 11 or 12 bristles, of which two to four appear to be on mesepisternum (*MPS.*), the remainder on mesepimere (*MPM.*). Metanotum, together with its flange, slightly longer than mesonotum; with three rows of bristles, none extending ventrad to midline. Metanotal flange with a dorso-apical tooth. Lateral metanotal area (*L.M.*) almost twice as long as broad; with two bristles, dorsomarginal the longer. Metepisternum (*MTS.*) with one long bristle in posterodorsal region. Metepimere (*MTM.*) with about seven long bristles arranged 3-3-1.

Legs.—Profemur with about four lateral nonmarginal bristles, mesofemur and metafemur with about three or four subapical, lateral bristles; none on apicoventral flange. Legs long and narrow, e.g., metatarsal segment one almost six times as long as broad. Protibia (Fig. 2) with five pairs of dorsomarginal bristles and with a single stout bristle between dorsalmost and second pairs and another such bristle between third and fourth pairs. Mesotibia and metatibia the same but three of these pairs much more conspicuous and of longer bristles than the others; also differing in that there are two single stout bristles between third and fourth pairs. None of tarsal bristles reaching beyond apex of following segment. Measurements (in microns) of tibiae and segments of tarsi (petiolate base deleted) of holotype:

Leg	*Tibia*	*Tarsal Segments*				
		I	*II*	*III*	*IV*	*V*
Pro-	225	95	90	80	55	120
Meso-	340	190	145	100	60	125
Meta-	450	330	220	135	75	140

Abdomen.—First tergum (*1T.*) with two rows of bristles and one or two subdorsal spinelets. Basal sternum with one ventromarginal bristle on each side. Terga II to V with with one apical spinelet per side. Second terga with first row of bristles represented by three bristles, third and fourth terga with one or two such bristles; remaining unmodified terga with but one row of bristles; second row of bristles extending slightly below spiracle in each case. Typical sterna with two subdorsal bristles per side. Antepygidial (antesensilial) bristles with middle bristle twice length of lower bristle; upper bristle slightly shorter than lower.

Modified abdominal segments (Fig. 4).—Eighth tergum (*8T.*) extending as far caudad as base of acetabulum and ventrad to upper portion of aedeagal apodeme; with a long apical bristle and two long median bristles, one of these below sensilium. Eighth sternum extending apicad only to about level proximad of midpoint of distal arm of ninth sternum; extending dorsad slightly above manubrium and therefore somewhat broader than long; with two subventral bristles.

Immovable process of clasper (*P.* and Fig. 3.) subovate, about two-thirds or three-fourths as broad as long; dorsal margin slightly convex; ventral margin evenly convex, caudal margin fairly straight. Process *P.* with two dorsomarginal subapical bristles and two or three much smaller bristles adjacent to anteromost of these; caudal margin with a subapical bristle and a longer bristle well above midpoint, the last suggestive of characteristic bristle of so many leptopsylline fleas and perhaps homologous with acetabular bristles of true ceratophyllid fleas. Movable finger or digitoid (*F.*) inserted relatively well proximad on *P.*; almost twice as long as broad, but basally recurved; anterior margin apically fairly straight; posterior margin convex. *F.* with two long bristles, one at midpoint and one at proximal third; caudal margin with three or four much smaller bristles above stout median bristle; then a few scattered hairs. Manubrium (*MB.*) long and narrow, apically somewhat upturned.

Ninth sternum with proximal arm (*P.A.9*) slightly longer than distal arm (*D.A.9*); relatively long and narrow, apically subacuminate, resembling slightly crooked finger. Distal arm of ninth sternum (*D.A.9* and Fig. 6.) also relatively long and narrow. Morphological ventral

margin markedly sinuate at apical third, the resulting convexity or lobe bearing four bristles, two of which are quite long; apical portion of arm above sinus distally ovate; with three subapical marginal thin bristles; with about five or six dorsomarginal bristles and three or four small scattered bristles. Aedeagal apodeme (*AE.A.*) almost three times as long as portion of aedeagus distad of apodemal strut; over three times as long as broad; with a very well developed apical appendage (*AP.A.*) and a well-developed proximal spur (Fig. 9, *P.S.*). Median dorsal lobe (*M.D.L.*) shallowly convex and turning straight ventrad; apically subtruncate and recurved; with a pair of long narrow apicomedian sclerites (*A.M.S.*) which are distally angled and expanded ventrad. Crochets (*CR.*) very large, longer than endchamber distad of apodemal strut; twice as long as broad, but with apical half conspicuously narrowed and upcurved, so that distal portion of crochet resembles geologist's hammer. Sclerotized inner tube (*S.I.T.*) fairly short, about twice as long as broad at maximum, oblique, with distinct sclerotized band of inner tube (*B.I.T.*) extending from its apex. Armature of inner tube (*A.I.T.*) represented as two dorsal spurs. Lateral lobes (*L.L.*) weakly sclerotized, extending from wall of aedeagal pouch to base of crochet at proximal portion of *S.I.T.* Wall of aedeagal pouch (*P.W.*) extending as a straight line from proximal spur; ventrally somewhat convex. Penis rods (*P.R.*) long but not fully coiled, paralleling apodemal rod of ninth sternum. Ventral intramural rod of endophallus (*I.R.*) heavily sclerotized. Sclerites of apodemal strut (*AP.S.*) not clearly defined. Tenth segment conspicuous; sensilium (Fig. 4, *SN.*) very flat; with about 17 pits per side. Dorsal lobe of proctiger (*D.A.L.* and Fig. 5.) with four or five dorsomarginal and two ventromarginal bristles. Ventral lobe (*V.A.L.*) of proctiger with two subapical ventromarginal bristles, its dorsal margin weakly sclerotized.

The species is named for Dr. J. R. Audy, director of the Colonial Office Scrub Typhus Research Unit, Kuala Lumpur, Malaya, who has contributed much to our knowledge of arthropod-borne diseases. As a member of the U. S. Army Medical Research Units in Malaya and Borneo, 1948–1951, I am particularly indebted to him for his splendid cooperation throughout the course of our investigations.

DISCUSSION OF THE SUBFAMILY LEPTOPSYLLINAE

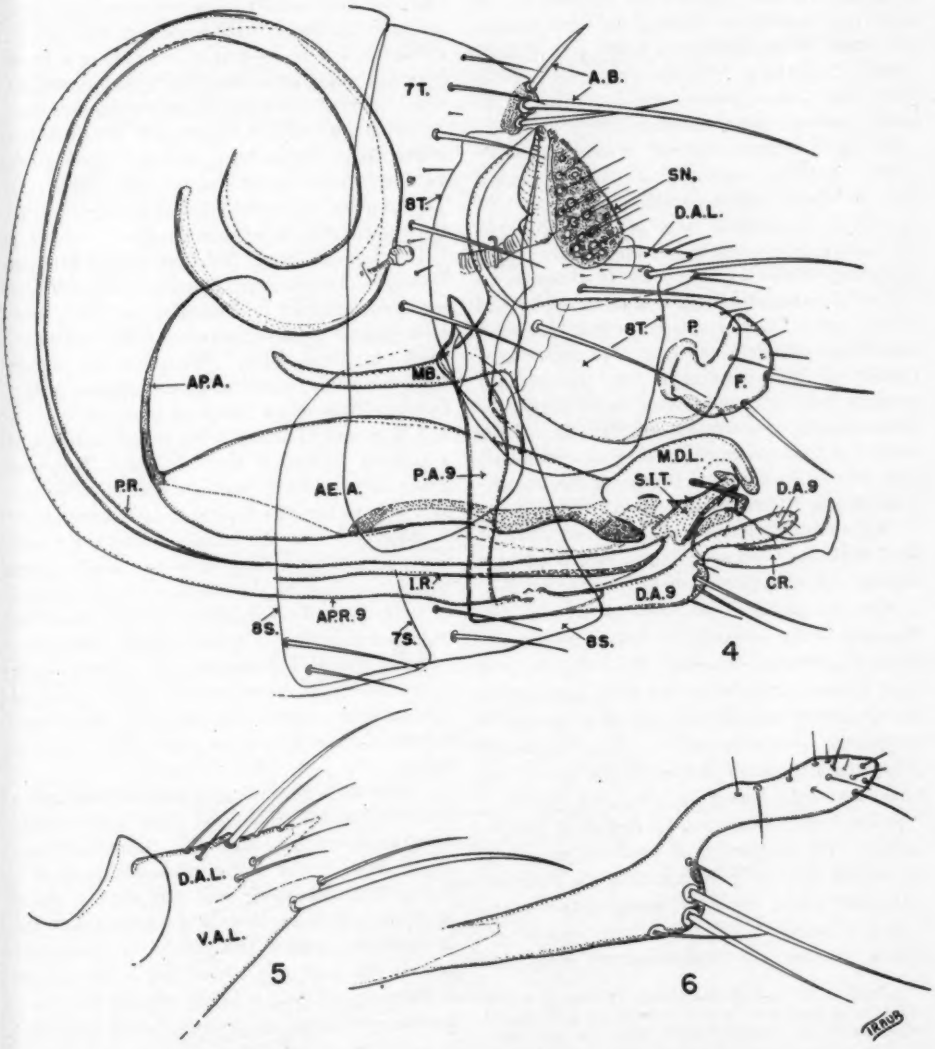
Fleas of the subfamily Leptopsyllinae are characteristic parasites of murid and cricetid rodents and of certain insectivores. As a group these fleas are widely distributed, indigenous forms being known from Europe; much of Asia, including the Middle East, Asiatic U.S.S.R., and China; Africa; North America; New Guinea; North Borneo and the Philippines.[2] Some confusion exists in the literature as to the systematic position of *Leptopsylla* Jordan and Rothschild, 1911, and its allies: *Peromyscopsylla* I. Fox, 1939, *Pectinoctenus* Wagner, 1929, *Paractenopsyllus* Wagner, 1938, and *Sigmactenus* Traub, 1950. According to the traditional emphasis upon presence of a genal comb and of a fracticipit head-capsule, these fleas belong to the Hystrichopsyllidae. More recent workers, studying independently, and to a certain extent utilizing different morphological characters, have stated that this complex belongs with the ceratophyllid fleas (*3*, *4*, *6*, *7*). It is felt by these students that the presence or absence of genal spines or a fracticipit condition does not necessarily indicate fundamental relationship. For this reason Traub (*6*) restored the combless[3] *Catallagia* Rothschild, 1915, to proximity with the combed *Epitedia* Jordan, 1938, and *Neopsylla* Wagner, 1903 (a position intended by the authors), instead of leaving it in the "Dolichopsyllidae" where it had been placed among combless fleas which were otherwise very different morphologically (*1*, *2*).

Leptopsylla and allies agree with the ceratophyllid fleas in the following characters (*partim*): (1) Metanotum with apical spines; (2) sensilium dorsally straight; (3) male with third aedeagal rod arising as a tendon from the ninth sternum; (4) male eighth tergum large, enclosing much or most of genitalia; (5) male eighth sternum correspondingly reduced, covering relatively little of genitalia; (6) aedeagal crochets typically very large, movable, articulated ventrally near base of sclerotized inner tube.

[2] *Acropsylla* Rothschild is now regarded by some workers as belonging in the tribe Mesopsyllini, subfamily Amphipsyllinae, a group of fleas related to the Leptopsyllinae, as shown below. *Acropsylla* occurs in India and Burma.

[3] The comb referred to is the genal ctenidium and not the pronotal comb.

In contrast, the Hystrichopsyllidae may be characterized as follows: (1) Metanotum lacking apical spines; (2) sensilium more or less convex; (3) third aedeagal rod free, lying within end-chamber and not definitely arising as a tendon from the ninth sternum; (4) male eighth tergum reduced, enclosing very little of genitalia; (5) male eighth sternum correspondingly enlarged, ensheathing much of genitalia; (6) crochets relatively small, not freely movable.



JOHNSONAEPSYLLA AUDYI, N. GEN., N. SP.

FIG. 4.—Modified abdominal segments, male. FIG. 5.—Dorsal and ventral anal lobes. FIG. 6.—Distal arm of ninth sternum.

The Leptopsyllinae[4] prior to the discovery of *Johnsonaepsylla*, n. gen., could be separated from true ceratophyllids thusly: (1) Genal comb present; (2) arch of endoskeleton visible as tentorial arm (Fig. 1, *T.A.*) in front of eye; (3) fracticipit; (4) antennal groove closed so that club of male antenna does not extend onto propleuron; (5) upper eye bristle not directly in front of eye, (6) some of head bristles stout and slightly curved, "spiniform"; (7) an ovate pale area or ring (Fig. 1, *RO.*) above ventral margin of antennal groove, near midpoint of groove; (8) male eighth tergum relatively smaller, not completely enclosing genitalia, extending caudad only to about middle of claspers and ventrad to middle of proximal arm of ninth sternum; (9) male eighth sternum correspondingly larger, extending dorsad to near base of clasper.

The following additional characters are typical of the Leptopsyllinae but *may* occur in true ceratophyllids: (10) Eye vestigial; (11) dorsolateral bristles of tibia forming a false comb; (12) crochets lacking a well-defined basal peglike or barrel-shaped sclerotization (if the peg is indicated it is ventromarginal); (13) a characteristic, long submedian marginal bristle on the immovable process (items 10 through 13 rarely occur in the Ceratophyllidae); (14) last segment of tarsi with four pairs of stout lateral plantar bristles and one pair of mesal plantar bristles.

Johnsonaepsylla, n. gen., does not fit with this diagnosis of the subfamily in that it possesses a distinct (although somewhat reduced) eye, and lacks a genal comb, while the tibial false combs are so reduced (or undeveloped) as to be almost inapparent. *Johnsonaepsylla* is also unique in possessing five lateral plantar bristles on the last tarsal segment of each leg.

It has been pointed out above that it is compatible with a concept of dynamic evolution for related fleas to differ regarding the presence of a genal comb. Similarly, many instances are known in which "blind" fleas very closely resemble species with well-developed eyes. Indeed, reduction of eyes in fleas is frequently adaptive and correlated with parasitism of subterranean and/or nocturnal hosts (cf. *Pulex sinoculus* Traub, 1950, and *P. irritans* Linnaeus (*6*)). The presence of a genal ctenidium is highly correlated with that of a reduced eye, while combless fleas usually have well-developed eyes, unless parasitizing a subterranean host (*6*, *8*). *Jellisonia* Traub, 1944, is an example of a genus in which certain species have well-developed tibial "combs" and others have lost this structure on some legs (*6*, *9*). *Stivalius* is another case where some forms have well-developed tibial "combs," while most species lack them (*5*). The number of lateral plantar bristles on the tarsi also varies in related genera.

For these reasons I feel that these differences between *Johnsonaepsylla* and other leptopsyllines are secondary, not fundamental, and that *Johnsonaepsylla* is merely an unspecialized if not somewhat primitive form. *Johnsonaepsylla* agrees with the basic, essential characteristics of the leptopsyllines—those listed as numbers 2, 3, 4, 6, 7, 8, 9, and 13 above, while its genitalia are of a pattern typical of the subfamily. This new genus agrees with *Leptopsylla* and allies in two other characteristics typical (but not exclusive) of the group—viz, the maxillary lobe has a relatively well sclerotized wing which clearly arises anterior to base of the maxillary palpi, instead of being virtually invisible as in most fleas; the male proctiger has a distinct basal transparent collar or flange. The preantennal region is much more rounded in *Johnsonaepsylla* than in typical leptopsyllines, where this region is subconical. However, *Paractenopsyllus* also lacks a conical frons.

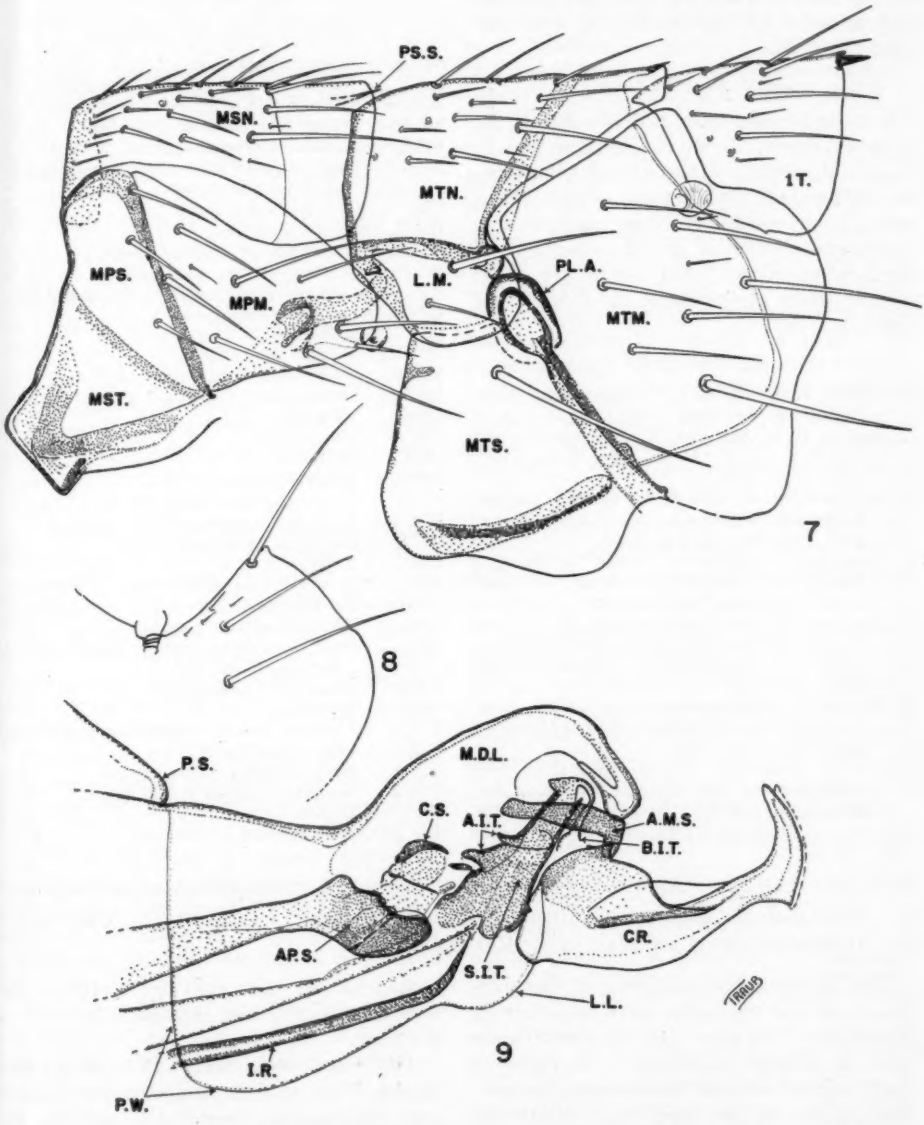
Johnsonaepsylla indicates a close relationship with the Amphipsyllinae and in my opinion links the Leptopsyllinae with the Amphipsyllinae. Thus, fleas of the latter subfamily possess a visible tentorial arch, and may lack a genal ctenidium. At times there is an indication of the interantennal suture and certain of these fleas possess the pale ring above the lower margin of the antennal groove. Some of these fleas have distinct eyes, while pre-antennal bristles modified so as to suggest spiniforms occur in *Ctenophyllus* Wagner, 1927. In the Amphipsyllinae, however, the male eighth sternum is well developed, large, and/or modified. The head is normally integrecipit, and if there is a suture indicated, it is not as apparent as in *Johnsonaepsylla*, in

[4] Jordan, in Smart (*4*), treats *Leptopsylla* and allies in a separate family within an undeclared superfamily of ceratophyllid fleas. *In litt.*, Dr. Jordan agrees that certain of the "families" in this chapter could equally well be considered "subfamilies" today, as I am doing in this paper. Our present state of knowledge of the higher classification of fleas is insufficient to categorically define superfamilies, families, and subfamilies, even though many authors now agree as to the various "groups" of fleas.

which it is well developed as in such typical leptopsyllids as *Peromyscopsylla*. The peglike sclerotization of the crochet is usually well indicated in the Amphipsyllinae.

SUMMARY

Johnsonaepsylla audyi, n. gen. and n. sp., collected ex *Hylomys* on Mount Kinabalu, North Borneo, is described and figured.



JOHNSONAEPSYLLA AUDYI, N. GEN., N. SP.

FIG. 7.—Mesothorax and metathorax. FIG. 8.—Eighth tergum (*partim*), male. FIG. 9.—Apical portion of aedeagus.

The genus is unique in the subfamily Leptopsyllinae in that it lacks a genal ctenidium and it possesses a distinct eye and has five pairs of lateral plantar bristles on the last segment of the tarsi. While essentially an unspecialized leptopsylline flea, the new genus links this subfamily with the Amphipsyllinae.

ACKNOWLEDGMENTS

I am indebted to Dr. Karl Jordan, F. R. S., and Messrs. G. H. E. Hopkins and F. G. A. M. Smit, of the British Museum, for verification of the status of this interesting genus and for pertinent and valuable comments. Certain of the characteristics of the Leptopsyllinae listed herein are based in part upon observations by Jordan and Hopkins *in litt.*

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LIST OF ABBREVIATIONS

AE.A.	Aedeagal apodeme.
A.I.T.	Armature of inner tube of aedeagus.
A.M.S.	Apicomedian sclerites of aedeagus.
AP.A.	Apical appendage of aedeagus.
AP.S.	Sclerite of apodemal strut.
B.I.T.	Band of inner tube extending distad of apex of sclerotized inner tube.
CR.	Crochet of aedeagus.
D.A.L.	Dorsal anal lobe.
D.A.9	Distal arm of ninth sternum.
F.	Digitoid or movable finger.
I.R.	Ventral intramural rod of endophallus.
L.M.	Lateral metanotal area.
MB.	Manubrium
M.D.L.	Median dorsal lobe.
MPM.	Mesepimere
MSN.	Mesonotum
MPS.	Mesepisternum
MTM.	Metepimere
MST.	Mesosternum
MTS.	Metepisternum
P.	Immovable process of clasper.
P.A. 9	Proximal arm of ninth sternum.
PL.A.	Pleural arch of metathorax.
P.R.	Penis rods.
P.S.	Proximal spur of aedeagus.
PS.S.	Pseudoseta
P.W.	Wall of aedeagal pouch.
RG.	Pale ring above ventral margin of antennal groove.
S.I.T.	Sclerotized inner tube.
SN.	Sensilium
T.A.	Anterior tentorial arm of endoskeleton.
V.A.L.	Ventral anal lobe.
VC. 1	First vinculum or link-plate.
VC. 2	Second vinculum or link-plate.
8S.	Eighth sternum.
1T.	First tergum.

MALACOLOGY.—*Generic and subgeneric names in the molluscan class Scaphopoda.*[1]

WILLIAM K. EMERSON,[2] Museum of Paleontology, University of California.

(Communicated by Harald A. Rehder.)

The supraspecific categories of the molluscan class Scaphopoda have not received serious study for more than 50 years. In the light of present knowledge it is apparent that they are in need of taxonomic review. The purpose of this paper is to indicate the nomenclatural units that are available for future taxonomic and phylogenetic work in the class.

The Scaphopoda, the smallest of the five classes of the phylum Mollusca, are divided into the families Dentaliidae and the Siphonodentaliidae.[3] The families are distin-

[1] Contribution no. 66 from the Allan Hancock Foundation, University of Southern California.

[2] Formerly of the Allan Hancock Foundation, University of Southern California.

[3] D. K. Greger, 1933, p. 373, described *Thyropella typa*, n. gen., n. sp., from the Devonian of

guished from each other by differences in the median tooth of the radula, the form of the foot, and certain definite shell characters. The reader is referred to the excellent monographs by Pilsbry and Sharp (1897–98) and Henderson (1920) for keys which differentiate the two families and for the distinguishing characters of the genera and subgenera which comprise the two families.

With the exception of the fossil genus *Plagioglypta*, the genus *Dentalium* (*sensu lato*) has been considered by many taxonomists to include all the remaining representatives of the family Dentaliidae. Thus, the genus *Dentalium* has been divided into a number of subgenera, some of which are of much greater biological significance than others. On the other hand, most students have recognized for the Siphonodentaliidae three genera, *Entalina*, *Siphonodentalium*, and *Cadulus*. The last named has been divided into several subgenera and sections. While some of these nomenclatural units are useful for distinguishing evolutionary trends, many are objectionable synonyms of no apparent taxonomic significance.

A number of tubiculous gastropod shells and calcareous worm tubes were described as scaphopods during the early period of systematics. Thus, tubes of the gastropod family Caecidae and the annelid family Serpulidae form a sizable list of spurious scaphopods. Some of the Siphonodentaliidae were originally assigned to vermian genera by their describers.

Procedure.—All scaphopod generic and subgeneric names known to the writer are reviewed and the genotype (type species) of each valid supraspecific unit is indicated. In order to retain a purely objective approach, no distinction is made between genera, subgenera, and "sections." It is beyond the scope of this paper to evaluate their taxonomic rank. Such an evaluation is reserved for a future paper.

The nomenclatural units are listed alphabetically with the valid names in boldface letters and the invalid names in italics.[4] Although the capitalized names are valid, many are junior synonyms and, therefore, are not available taxonomically. Names which are objective synonyms[5] of earlier valid names are so indicated. Every effort has been made to rigidly follow the International Rules of Zoological Nomenclature in establishing the types of the genera. In order to prevent any misunderstanding with regard to the selection of the types, and thus the generic concepts, the reason governing the type selection is given. Fortunately, the majority of the names have original designations or are monotypic. In cases of subsequent designations, the species originally contained in the genus are listed together with the author and the date of the subsequent designation. By possessing these data the reader may determine the validity of possible earlier designations without having access to the original description. The source of the original description is cited for each genotype and reference is made to a generally accessible subsequent description and illustration. Inasmuch as the locality data for the fossil and living species were obtained principally from Pilsbry and Sharp (1897), the majority of the geologic age assignments is of that date.

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central Missouri. Should this actually prove to be a scaphopod, a new family would have to be formed to contain it.

[4] The changes in the Règles made by the 1948 meeting of the International Commission on Zoological Nomenclature became effective January 1, 1951. While the official Règles are not at this date in print, it is the author's understanding that under the revised Règles emendations of generic names whether justified or not, preoccupy for the purpose of homonymy, and erroneous emendations are available as junior synonyms in cases where the original names are later rejected. This change creates a rather unfortunate and nearly infeasible system for determining the next available junior synonym in cases of rejected names. Until this situation is clarified, it seems proper to consider unjustified emendations as being invalid and unavailable.

[5] Objective or absolute synonyms are those having identical genotype species.

GENERA AND SUBGENERA ALPHABETICALLY ARRANGED

DENTALIIDAE

Antale Sacco, 1896, p. 97, for *Antale vulgare* (Da Costa), etc. Genotype: (by subsequent designation, Sacco, 1897, p. 98) *Antale vulgare* (Da Costa), 1778, p. 28; Pilsbry and Sharp, 1897, p. 41, pl. 8, figs. 22–24. Recent, Mediterranean and Adriatic Seas, Northeastern Atlantic Ocean; Pliocene of Italy. Name taken from *Antale* of "Aldrov. [andus] 1618." A junior objective synonym of *Dentale* Da Costa, 1778. Used by subsequent authors, e. g., Rovereto, 1900, p. 201, and Cossmann and Peyrot, 1916, p. 160.

Antalis Herrmannsen, 1846, vol. 1, p. 63 (genus without species; first species assigned by H. and A. Adams, 1854, vol. 1, p. 457, for 16 species, including "*Antalis entalis* Linn."). Genotype: (by subsequent designation, Pilsbry and Sharp, 1897, p. 37) *Dentalium entalis* Linné, 1758, p. 758; Pilsbry and Sharp, 1897, p. 42, pl. 8, fig. 25. Recent, North Atlantic Ocean. Herrmannsen, 1846, proposed *Antalis* without species from *Antale* Aldrovandus, 1606, see Emerson, 1951, p. 17. *Antalis* is often attributed to H. and A. Adams, 1854, vol. 1, p. 457, genotype: (by subsequent designation, Pilsbry and Sharp, 1897, p. 37) *Dentalium entalis* Linné, 1758, p. 758.

Bathoxiphus Pilsbry and Sharp, 1897, p. 121, for *Dentalium ensiculus* Jeffreys, 1877, *D. ensiculus* var. *didymum* Watson, 1879. Genotype: (by subsequent designation, Boissevain, 1906 p. 48) *Dentalium ensiculus* Jeffreys, 1877, p. 154; Henderson, 1920, p. 81, pl. 14, figs. 1, 4, 5, 7, 9. Recent, Atlantic Ocean in deep water.

Coccodentalium Sacco, 1896, p. 98. Genotype: (by original designation) *Coccodentalium radula* (Schroeter, 1784), p. 530; Sacco, 1897, p. 111, pl. 10, figs. 7–21. Miocene, Piedmont of Italy.

Compressidens Pilsbry and Sharp, 1897, p. 123. (See under family Siphonodentaliidae.)

Dentale Da Costa, 1778, p. 24. Genotype: (by monotypy) *Dentale vulgare* Da Costa, 1778, p. 24, pl. 2, fig. 10; Pilsbry and Sharp, 1897, p. 41, pl. 8, figs. 22–24. Recent, Mediterranean and Adriatic Seas; Atlantic Ocean from Spain to Belgium, etc.; Miocene of Belgium, Pliocene of Italy. For a review of the synonymy of this unit see Emerson, 1951, p. 19.

Dentalia Perry, 1811, pl. 52, for *Dentalia viridis* Perry, 1811, *D. bandata* Perry, 1811, *D. denacta* Perry, 1811. Genotype: (here designated) *Dentalia viridis* Perry, 1811, p. 52 = *Dentalium elephantinum* Linné, 1758. As a result of the above designation, *Dentalia* is a junior "objective" synonym of *Dentalium* Linné, 1758.

Dentalinm Pilsbry and Sharp, 1897, p. xxviii. Error for *Dentalium* Linné, 1758.

Dentalites Schlotheim, 1813, pp. 91, 100, 110, for *Dentalitus striatus*, *D. obsoletus*, and *D. minutus*, nude names. Genotype: (here designed) *Dentalium elephantinum* Linné, 1758, p. 785. With the above designation *Dentalites* is a junior objective synonym of *Dentalium* Linné, 1758.

Dentalium Linné, 1758, p. 785, for *D. elephantinum* L., *D. Dentalis* L., *D. Entalis* L., *D. minutum* L. Genotype: (by subsequent designation, Montfort, 1810, p. 23) *Dentalium elephantinum* Linné, 1758, p. 785; Pilsbry and Sharp, 1897, p. 1, pl. 1, figs. 1–7. Recent, Amboyna and Philippine Islands.

Dentalius Forbes, 1841, p. 253, for "*Dentalius Entalis.*" Error for *Dentalium* Linné, 1758.

Dertalium Krotow, 1885, p. 153. Error for *Dentalium* Linné, 1758.

Entale Herrmannsen, 1848, vol. 1, p. 423 (genus without species). Genotype: (here designated) *Dentalium elephantinum* Linné, 1758, p. 785. As a result of the above designation, *Entale* is a junior objective synonym of *Dentalium* Linné, 1758. Name taken from *Entale* of Tournefortio in Gualtieri, 1742. No species were validly assigned but a brief description was given.

Entaliopsis Newton and Harris, 1894, p. 66. Genotype: (by original designation) *Dentalium entalis* Linné, 1767, p. 1263 = *D. entalis* Linné, 1758, p. 785. Proposed as a new name for the preoccupied *Entalis* of Gray, 1847, not Sowerby, 1839, an annelid genus. *Entaliopsis* is a junior objective synonym of *Antalis* Herrmannsen, 1846.

Entalis Gray, 1847, p. 158. Genotype: (by original designation) "*Dentalium e.*[*ntalis*] Desh. [ayes] 1825" p. 359 = *Dentalium entalis* Linné, 1785, p. 785; Pilsbry and Sharp, 1897, p. 43, pl. 8, fig. 25. Recent, Atlantic Ocean. Not *Entalis* Sowerby, 1839, p. 42 (Annelida, Serpulidae). A junior objective synonym of *Antalis* Herrmannsen, 1846.

Episiphon Pilsbry and Sharp, 1897, p. 117, for *Dentalium sowerbyi* Guilding, 1834, *D. fistula* Sowerby, 1860, *D. filum* Sowerby, 1860, *D. innumerabile* Pilsbry and Sharp, 1897, *D. subrectum* Jeffreys, 1882, *D. longum* Sharp and Pilsbry, 1897, *D. tornatum* Watson, 1879. Genotype: (by subsequent designation, Suter, 1913, p. 821) *Dentalium sowerbyi* Guilding, 1834, p. 35, pl. 3, fig. 7; Henderson, 1920, p. 77, pl. 13, figs. 2, 3, 10. Recent, off Southeastern United States and West Indies.

Eudentalium Cotton and Godfrey, 1933, p. 140. Genotype: (by original designation) *Dentalium quadricostatum* Brazier, 1877, p. 58. Recent, Princess Charlotte Bay, Australia; Katow, New Guinea.

Fissidentalium Fischer, 1885, p. 894. Genotype: (by monotypy) *Dentalium ergasticum* Fischer, 1882, p. 275; Pilsbry and Sharp, 1897, p. 74, pl. 15, figs. 35–36. Recent, Gulf of Gascony and Atlantic Ocean in deep water.

Fustaria Noszky, 1936, p. 83. Error for *Fustiaria* Stoliczka, 1868.

Fustiaria Stoliczka, 1868, p. 439, for *Dentalium circinatum* Sowerby, 1823, *D. eburneum* Lamarck, 1818 = *D. eburneum* Linné, 1767. Genotype: (by subsequent designation, Newton and Harris, 1894, p. 64) *Dentalium eburneum* Linné, 1767, p. 1264; Pilsbry and Sharp, 1897, p. 115, pl. 20, figs. 33, 34. Recent, South Pacific.

Gadilina Foresti, 1895, p. 259. Genotype: (by monotypy) *Siphonodentalium* (*Gadilina*) *triquetrum* (Brocchi), 1814, p. 628; Sacco, 1897, p. 113, pl. 10, figs. 35–46. Miocene, Piedmont of Italy.

Graptacme Pilsbry and Sharp, 1897, p. 85, for *D. sericatum* Dall, 1881, *D. circumcinctum* Watson, 1879, *D. eboreum* Conrad, 1846, *D. leptum* Bush, 1885, *D. semistriatum* Turton, 1819, *D. semistriatum* var. *semipolitum* Broderip and Sowerby, 1829, *D. aciculum* Gould, 1859, *D. novaehollandiae* Chenu, 1858, *D. acutissimum* Watson, 1879, *D. inversum* Deshayes, 1825, *D. splendidum* Sowerby, 1832. Genotype: (by subsequent designation, Woodring, 1925, p. 201) *Dentalium eboreum* Conrad, 1846, p. 27; Pilsbry and Sharp, 1897, p. 89, pl. 16, figs. 47–49, 55–56. Recent, off Southeastern United States and West Indies.

Heteroschisma Simroth in Bronn, 1895, p. 460, for *Dentalium inversum* Deshayes, 1825, *D. subterfissum* Jeffreys, 1877, *D. Leoninae* Meunier, 1878. Genotype: (here designated) *D. subterfissum* Jeffreys, 1877, p. 154; Pilsbry and Sharp, 1897, p. 61, pl. 7, figs. 15–19. Not *Heteroschisma* Wachsmuth, 1883, (Echinodermata), nor Kofoid and Skogsberg, 1928, (Protozoa). Since this is not considered to be a natural biological unit no new name is here proposed.

Laevidentalium Cossmann, 1888, p. 7. Genotype: (by original designation) *Dentalium incertum* Deshayes, 1825, p. 362, pl. 7, fig. 17. Eocene of Paris Basin.

Lobantale Cossmann, 1888, p. 7. Genotype: (by original designation) *Dentalium duplex* Defrance, 1819, p. 71; Pilsbry and Sharp, 1898, p. 203, pl. 39, fig. 12. Eocene of Paris Basin.

Paradentalium Cotton and Godfrey, 1933, p. 139. Genotype: (by original designation) "*D. [entalium] intercalatum* Gould, 1859," p. 166; Pilsbry and Sharp, 1897, p. 23, pl. 11, figs. 88–89. Recent, "China Seas." Cotton and Ludbrook, 1938, p. 218, state that *D. intercalatum* of Cotton and Godfrey, 1933, was misidentified, being actually *D. bednalli* Pilsbry and Sharp, 1897, p. 248, and that the genotype of *Paradentalium* thus should be considered the *D. bednalli*. In the case of a misidentified genotype, the original genotypic concept can not be changed once formulated unless an appeal is made to and is favorably acted upon by the Commission.

Plagioglypta Pilsbry and Sharp, 1897, p. xxxi. Genotype: (by original designation) *Dentalium undulatum* Muenster, in Goldfuss, 1844, p. 3, pl. 166, fig. 8. Triassic, St. Cassian, Tyrol mountains.

Prodentalium Young, 1942, p. 120. Genotype: (by original designation) *Prodentalium raymondi* Young, 1942, p. 120, pl. 20, figs. 3–6, 8, 12. Pennsylvanian, Magdalena group, New Mexico.

Pseudantalis Monterosato, 1884, p. 32, for *Dentalium fissura* Lamarck, 1818, *D. inversum* Deshayes, 1825, *D. rubescens* Deshayes, 1825, *D. tenuifissa* Monterosato, 1884, *D. filum* Sowerby, 1860. Genotype: (by subsequent designation, Sacco, 1897, p. 111) *Pseudantalis rubescens* (Deshayes), 1825, p. 363, pl. 16, figs. 23–25; Pilsbry and Sharp, 1897, p. 105, pl. 19, fig. 2. Recent, Mediterranean Sea; Pliocene of Italy.

Schizodentalium Sowerby, 1894, p. 158. Genotype: (by monotypy) *Schizodentalium plurifissuratum* Sowerby, 1894, p. 158, pl. 12, fig. 24; Pilsbry and Sharp, 1897, p. 82, pl. 6, figs. 87–89. Recent, "Hong Kong?"

Rhabdus Pilsbury and Sharp, 1897, p. 112. Genotype: (by original designation) *Dentalium rectius* Carpenter, 1865, p. 59; Pilsbry and Sharp, 1897, p. 113, pl. 21, fig. 45. Recent, Eastern North Pacific Ocean.

Tesseracme Pilsbry and Sharp, 1898, p. 249, for "group of *D. quadrapicale*" = *Dentalium dispar* Sowerby, 1860, *D. quadricostatum* Brazier, 1877, *D. dipsycha* Pilsbry and Sharp, 1897, *D. quadrapicale* Sowerby, 1860, *D. tesseragonum* Sowerby, 1832, *D. quadrangulare* Sowerby, 1832, *D. fisheri* Pilsbry and Sharp, 1897. Genotype: (by subsequent designation: Woodring, 1925, p. 119) *Dentalium quadrapicale* Sowerby, 1860, p. 103, pl. 225, fig. 61; Pilsbry and Sharp, 1897, p. 34, fig. 50. Recent, Cochin and Malabar, Eastern seas.

SIPHONODENTALIIDAE

Cadulus Philippi, 1844, p. 209. Genotype: (by monotypy) *Dentalium ovulum* Philippi, 1844, p. 208, pl. 27, fig. 21; Pilsbry and Sharp, 1898, p. 157, pl. 32, figs. 40–41. Recent, southern Italy; Pliocene of Calabria and Sicily; Miocene of Piedmont, Italy.

Cladulus Jaeckel, 1932, p. 311, (caption for text fig. 9). Error for *Cadulus* Philippi, 1844.

Compressidens Pilsbry and Sharp, 1897, p. 123. Genotype: (by original designation) *Dentalium pressum* Sharp and Pilsbry, 1897, p. 124, pl. 22, figs. 50–52; new name for *D. compressum* Watson, 1879, p. 516, not D'Orbigny, 1850, p. 233. Recent, Caribbean to off Florida Keys. The taxonomic position of this genus is somewhat uncertain. Though it is generally placed in the family Dentaliidae,-a reexamination of the anatomy may necessitate placing it in the Siphonodentaliidae.

Dicides Pilsbry and Sharp, 1898, p. 253. Error for *Discides* Sacco, 1897.

Discides Sacco, 1897, p. 115. Error for *Dischides* Jeffreys, 1867.

Dischides Jeffreys, 1867, p. 251. Genotype: (by monotypy) *Dentalium bifissum* S. Wood, 1848, p. 190, pl. 20, fig. 3 = *Ditrupa polita* S. Wood, 1842, p. 459, pl. 5, fig. 14; Pilsbry and Sharp, 1898, p. 144, pl. 27, figs. 90–94. Recent, Mediterranean and Eastern Atlantic; Pliocene of England and Italy. The designation of the type might possibly be interpreted as being by original designation as Jeffreys, 1867, states, "*D. bifissum* Searles Wood, from the Coralline Crag, is possibly of the type of another genus, for which I would suggest the name of *Dischides*."

Entalina Monterosato, 1872, p. 27, for "*Dentalium ?tetragonum*, Brocc." = "*D. quinquangulare*, Forbes." Genotype: (by subsequent designation, Sacco, 1897, p. 114) *Entalina tetragona* (Brocchi), 1814, p. 627, pl. 15, fig. 26; Pilsbry and Sharp, 1898, p. 234, Miocene of northern Italy and Vienna Basin.

Gadila Gray, 1847, p. 159, no. 280. Genotype: (by original designation) *Dentalium gadus* Montagu, 1803, p. 496, pl. 14, fig. 7; Pilsbry and Sharp, p. 186, pl. 31, figs. 28–32. Recent, British Channel, *fide* Montagu, 1803.

Gadilopsis Woodring, 1925, p. 206. Genotype: (by original designation) *Ditrupa dentalina* Guppy, 1873, p. 87, pl. 1, fig. 11; Pilsbry and Sharp, 1898, p. 190, pl. 36, figs. 21–22. Miocene of Jamaica.

Gadus "Rang" Deshayes, 1861 ("1864"), p. 217, for *Gadus parisiensis* Deshayes, 1861, *G. bilabiatus* Desh., 1861, *G. brevis* Desh., 1861. Not *Gadus* of Rang, 1829, p. 498, nor of Linné, 1758, pp. 242, 251. Deshayes, 1861, incorrectly assigned three "new" species from the Paris Basin to the pteropod genus *Gadus* of Rang, 1829; *Gadus* of Linné, 1758, a fish genus, is the first valid use of the name. Conrad, 1866, p. 75, used "*Gadus*, Montagu? Rang, 1829" for *Dentalium clavatus* Gould, 1859, *D. pusillum* Gabb, 1864, *D. subcoarctata* [*sic*] (Gabb), 1860, and *D. thallus* Conrad, 1834, considering *Helonyx* of Stimpson, 1865, a synonym.

Helonyx Stimpson, 1865, p. 63. Genotype: (by original designation) *Dentalium clavatum* Gould, 1859, p. 166; Stimpson, 1865, p. 63, pl. 9, fig. 14. Recent, Western Pacific, "Hong Kong."

Loxoporus Jeffreys, 1883, p. 664. Genotype: (by monotypy) *Cadulus olivi* (Scacchi), 1835, p. 56, pl. 2, fig. 6, a b; Pilsbry and Sharp, 1898, p. 170, pl. 31, figs. 33–35. Pliocene of southern Italy and Sicily.

Platyschides Henderson, 1920, p. 104. Genotype: (by original designation) *Cadulus grandis* Verrill, 1884, p. 219, pl. 44, fig. 20; Pilsbry and Sharp, 1898, p. 154, pl. 25, fig. 66. Recent, Western Atlantic, north of Cape Hatteras.

Polyschides Pilsbry and Sharp, 1898, pp. 142, 146. Genotype: (by original designation, p. 146) *Cadulus* (*Polyschides*) *tetraschistus* Watson, 1879, p. 521; Watson, 1885, p. 15, pl. 2, fig. 8. Recent, off Fernando Noronha, Brazil.

Pulsellum Stoliczka, 1868, p. 441, for *Siphonodentalium lofotense* M. Sars, 1865, *S. affine* M. Sars, 1865, *S. pentagonum* M. Sars, 1865. Genotype: (by subsequent designation, Cossmann, 1888, p. 11) *Pulsellum lofotense* (M. Sars), 1865, p. 297, pl. 6, figs. 29–33; Pilsbry and Sharp, 1897, p. 138, pl. 24, figs. 40–44. Recent, North Eastern Atlantic, Mediterranean and Aegean Seas; Pliocene of Calabria and Sicily.

Siphodentalis Paetel, 1888, p. 565. Error for *Siphonentalis* G. O. Sars, 1878, p. 104.

Siphodentalium Monterosato, 1874, p. 258. An invalid emendation of *Siphonodentalium* M. Sars, 1859. Other authors, including: Jeffreys, 1877, p. 155 (and later papers), and Watson, 1879, p. 519 (and later papers), have followed Monterosato in using this emendation.

Siphonentalis G. O. Sars, 1878, p. 104, for *Siphonentalis lofotensis* (M. Sars), 1865, *S. affinis* (M. Sars), 1865, *S. tetragona* "Brocchi" G. O. Sars = *Dentalium quinquangulare* Forbes, 1844, a member of the genus *Entalina* of Monterosato, 1872. Genotype: (here designated) *Siphonodentalium lofotense* M. Sars, 1865, p. 297, pl. 6, figs. 29–33; Pilsbry and Sharp, 1897, p. 138, pl. 24, figs. 40–44. Recent, North Eastern

Atlantic, Mediterranean and Aegean Seas; Pliocene of Calabria and Sicily. As a result of the above designation of *Siphonodentalium lofotense* as genotype, *Siphonentalis* becomes a junior objective synonym of *Pulsellum* Stoliczka, 1868.

Siphonodentalis Clessin, 1896, p. 30. Error for *Siphonentalis* G. O. Sars, 1878, p. 104.

Siphonodentalium M. Sars, 1859, p. 52. Genotype: (by monotypy) *Siphonodentalium vitreum* (M. Sars) = *D. vitreum* M. Sars, 1851, p. 178, (not Gmelin, 1791, p. 3739), = *Siphonodentalium lobatum* (Sowerby), 1860, p. 100, pl. 225, fig. 44. Recent, North Atlantic.

Siphonodontum Locard, 1887, p. 149 (contained in footnote). An invalid emendation of *Siphonodentalium* M. Sars, 1865, p. 296 = *Siphonodentalium* M. Sars, 1859, p. 52.

Tubidentalium Locard, 1887, p. 149, (contained in footnote). An invalid emendation of *Siphonodentalium* M. Sars, 1865, p. 296 = *Siphonodentalium* M. Sars, 1859, p. 52.

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NEMATOLOGY.—*The teasel nematode,* Ditylenchus dipsaci (*Kühn, 1857*), *Filipjev, 1936.*

WILBUR D. COURTNEY, Bureau of Plant Industry, Soils, and Agricultural Engineering. (Communicated by G. Steiner.)

Textile mills have long depended on the spiny heads or "burs" of cultivated teasel plants to produce the nap on fine woolens. Other materials have been tested for this use, but only nylon bristles have shown promise of success. Teasel culture constitutes an agricultural crop of extreme geographical limitations with the principal American planting being located in the Pacific Northwest.

The teasel is a biennial with a rosette of stout, coarse leaves attached to a fleshy crown during its first year. In late spring of the second year, a main stem with side branches rapidly grows or "runs" to a height of 4 to 7 feet and bears a spiny head at each terminal. When these heads are in the correct stage of development they are removed from the plant together with some 8 inches of stem. This is a hand operation, since the heads mature at three or four different times, depending on the part of the plant to which they may be attached. The harvested heads are placed in large, aerated sheds to cure, after which the salables are trimmed, graded to size and shipped to various textile mills. These teasel heads must be of uniform cylindrical shape and bear strongly attached spines in order to serve their purpose in finishing fine woolens.

The production of "puff balls" instead of sound heads, and the failure of second year plants to produce heads have resulted in various degrees of losses due to nematode infection. These losses have ranged from a trace, in a number of cases, to complete destruction, in a few isolated fields.

The bulb and stem nematode, *Ditylenchus dipsaci,* was first described by Kühn (*2*) in 1857 as the cause of "Kernfäule" of the inflorescence in fullers teasel, *Dipsacus fullonum* L. His description of the symptoms of nematode infection in teasels was confined to the characteristic misshapen, "soft shelled" heads or puff balls instead of the normal burs. Later, Ritzema Bos (*3*) reported negative results in his attempts to transfer the rye, onion and hyacinth populations of the bulb and stem nematode to teasel seedlings. His work was restricted since he had never observed nematode infection of teasel plants. These early investigations were quoted by later workers and little in addition was accomplished until Thorne (*4*) in 1945 illustrated and amended the diagnosis of the teasel nematode from the Pacific Northwest.

SYMPTOMS OF NEMATODE INFECTION

Bulb and stem nematodes usually enter teasel plants in the young seedling stage during prolonged moist conditions. They feed and reproduce in the young crowns and leaves, causing large populations to be built up under favorable circumstances. When the bud for the central shoot develops from an infected crown during the second year many nematodes attack the tissue surrounding the growing point, reproduce rapidly and are carried upward by plant

growth. They are present, therefore, when the growing points terminate in developing teasel heads or burs. The woody, vascular bundles surrounding the pith in the teasel head are so weakened by this infection that the bur gradually widens to a more or less spherical soft-walled mass. As the puff ball matures and becomes dry the nematodes collect in whitish masses in and near the pith as well as becoming attached to the

FIG. 1.—Teasel field showing severe nematode infection.

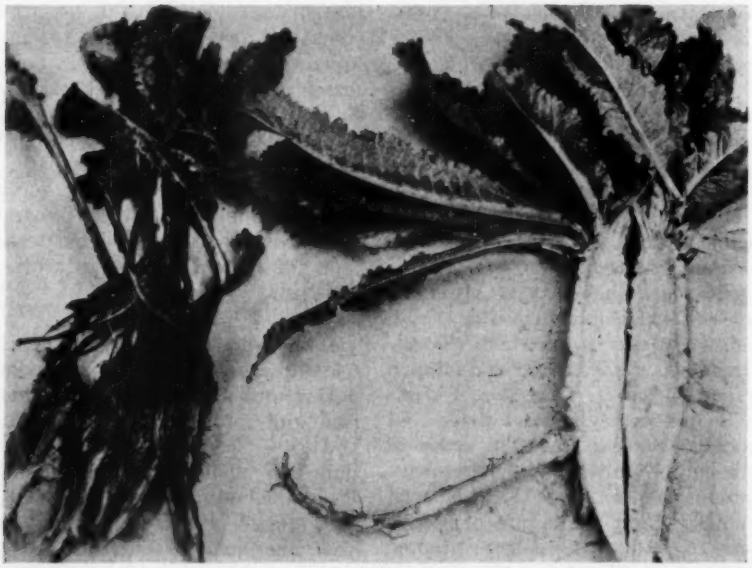


FIG. 2.—Close-up view of teasel plants, with their crowns cut open. Normal plant on right and infected plant on left. The pressure of cutting caused the weakened crown to break into the four sections.

pedicel of each seed. These nematode masses and those attached to the seed enter a quiescent stage in which they can live for at least 23 years, if kept dry, according to Fielding (*1*). Upon becoming moist the nematodes revive and may remain active for a year or two in moist soil without their host plant.

First year plants which are lightly infected may apparently grow well and give little indication of their weakened crowns. Moderately infected plants may survive during favorable seasons but are too weak to withstand poor growing conditions. Heavily infected plants develop leaves with discolored areas along their midribs, are often unduly curled and gradually die. In such cases the infection is chiefly concentrated in the crown, the tissue of which becomes discolored and progressively necrotic until, in last stages, only a tangled mass of vascular bundles remains within the crown covering. The discolored and distorted tissues contain all stages of these nematodes.

Second year plants which are lightly infected may appear normal with the exception of a few soft malformed heads. Moderately infected plants may be considerably dwarfed, produce puff balls instead of normal heads and often die prematurely.

TRANSFER OF TEASEL NEMATODE TO OTHER PLANTS

Studies of transfer of the present nematode from teasels to other plants were prompted by the finding of a few areas of infestation in a field of teasels which had not produced this crop for more than 10 years. As the teasel seed used for planting had been hot-water treated and was therefore nematode free, it appeared that the infestation had remained in the soil for that period of time, especially since no obvious method of spread could be determined. The following weeds growing on these areas were examined for nematode infection, with the results shown in Table 1:

As noted above, the only weeds having a nematode infection were the large-flowered collomia and the buckhorn plantain. No symptoms, however, were found in either of these plants. The plantain contained only limited numbers of preadult nematodes and very young adult forms, while considerable numbers of nematodes in all stages of

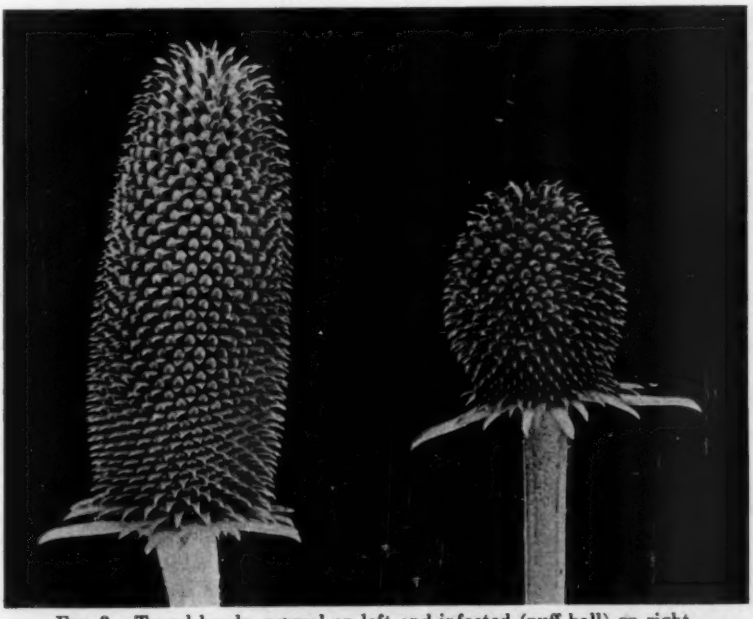


FIG. 3.—Teasel heads, normal on left and infected (puff ball) on right.

TABLE 1.—NUMBER OF INFECTED WEED PLANTS GROWING IN SOIL INFESTED WITH THE TEASEL NEMATODE

Plant	Total plants examined	Plants infected
Amaranth, redroot (*Amaranthus retroflexus* L.)	12	0
Bent grass, redtop (*Agrostis alba* L.)	4	0
Camomile, mayweed (*Anthemis cotula* L.)	20	0
Catsear, spotted (*Hypochoeris radicata* L.)	20	0
Collomia, large-flowered (*Collomia grandiflora* Dougl.)	35	20
Dandelion (*Taraxacum officinale* L.)	16	0
Dock, curly (*Rumex crispus* L.)	5	0
Fern, bracken (*Pteridium aquilinum pubescens* Underw.)	13	0
Fleabane, horseweed (*Erigeron canadensis* L.)	10	0
Gilia, skunkweed (*Gilia squarrosa* H. and A.)	5	0
Goosefoot, lambsquarters (*Chenopodium album* L.)	9	0
Knotweed, prostrate (*Polygonum aviculare* L.)	4	0
Lettuce, prickly (*Lactuca serriola* L.)	9	0
Plantain, buckhorn (*Plantago lanceolata* L.)	40	3
Radish, wild (*Raphanus raphanistrum* L.)	10	0
Ryegrass, Italian (*Lolium multiflorum* Lam.)	18	0
Salsify, meadow (*Tragopogon pratensis* L.)	10	0
Shepherdspurse (*Capsella bursa-pastoris* (L.) Moench)	3	0
Sorrel, sheep (*Rumex acetosella* L.)	20	0
Sowthistle, common (*Sonchus oleraceus* L.)	5	0
Thistle, bull (*Cirsium lanceolatum* (L.) Scop.)	14	0
Total	282	23

TABLE 2.—NUMBER OF INFECTED CROP PLANTS GROWING IN SOIL INFESTED WITH THE TEASEL NEMATODE AND IN GREENHOUSE TESTS WITH INOCULUM FROM OATS

Crop plant	Field Grown		Greenhouse Grown
	Spring	Winter	
	15 plants of each variety examined	48 plants of each variety examined	20 plants of each variety examined
Barley (*Hordeum vulgare* L.)	0	0	0
Clover, Hubam (*Melilotus alba* var. *annua* Coe)	0	0	0
Clover, crimson (*Trifolium incarnatum* L.)	0	0	0
Clover, red (*Trifolium pratense* L.)	0	0	1
Corn (*Zea mays* L.)	0	0	0
Oats, spring (*Avena sativa* L.)	0	15	6
Oats, winter (*Avena sativa* L.)	0	16	13
Peas, field (*Pisum sativum arvense* L.)	0	0	0
Rye, Rosen (*Secale cereale* L.)	0	0	8
Teasels (*Dipsacus fullonum* L.)	0	30	12
Vetch (*Vicia sativa* L.)	0	0	0
Wheat, spring (*Triticum aestivum* L.)	0	14	14
Wheat, winter (*Triticum aestivum* L.)	9	18	11

TABLE 3.—PERCENTAGE OF GERMINATION OF TEASEL SEED TREATED IN WATER AT DIFFERENT TEMPERATURES, DURATIONS, AND CHEMICALS ADDED (GERMINATION TESTS DETERMINED AT SEED LABORATORY, OREGON STATE COLLEGE)

Duration	Temp. °F.	Water	Water + Vatsol[1]	Water + Formalin[2]	Vatsol + Formalin[3]
(Untreated check)		91.6	90.7	93.1	93.2
1 hour	75	89.5	90.2	13.5	32.0
	120	78.5	61.2	40.5	0.0
	122	57.5	46.5	0.0	0.0
2 hour	75	89.5	92.5	6.0	14.7
	120	41.2	40.5	0.0	0.0
	122	12.0	9.7	0.0	0.0

[1] Vatsol O.S. used at rate of 8 oz. in 100 gallons of water.
[2] Formaldehyde solution U.S.P. 1 pint in 25 gallons of water.
[3] Vatsol and formaldehyde combined at the above rates.

development were usually found in the collomia.

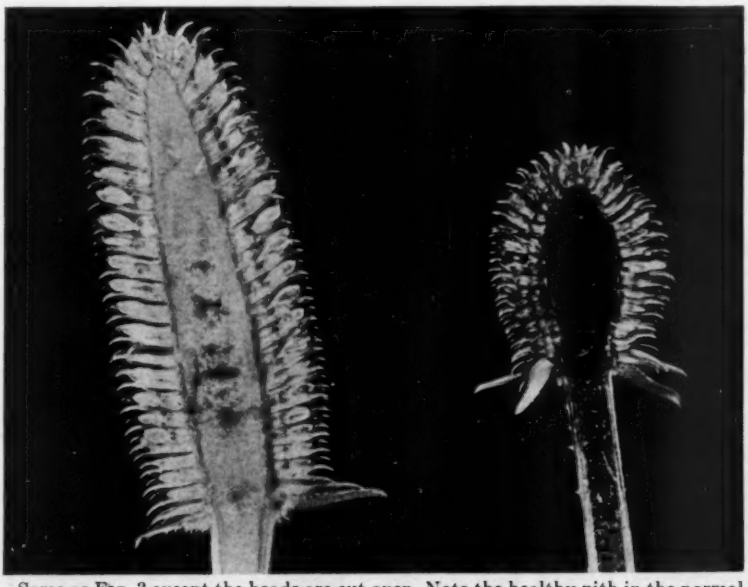
During the early spring of the following year attention was called to the unusual appearance of another field in which winter oats had been planted following an infected teasel crop. The uneven growth in this field showed as prominent spots of dead and dying oat plants. Upon examination these distorted plants resembled the "segging" or "tulip-root" as described by various workers and contained huge numbers of teasel nematodes. This observation indicated that winter oats might also have been serving as a host of the teasel nematode. To test this theory, oat plants infected from this soil were used to inoculate various crop plants growing in sterilized soil in pots in greenhouse tests listed in Table 2.

The same kinds of crop plants used in these greenhouse tests were also planted in a field which had recently produced heavily infected teasels. The weather was warm and dry that spring so that these plants rapidly grew to maturity and showed little infection upon examination. The following autumn they were re-planted on the same soil and slowly grew through the winter, under wet conditions. Results of the examination of both spring and fall planted crop plants, at their maturity, are presented in Table 2.

The infected crop plants listed above contained bulb and stem nematodes in all stages of development. These data show that several crop plants including oats, red clover, rye and wheat act as carriers of bulb and stem nematodes infecting teasels. It was possible to transfer the disease from winter oats to teasels and it may be that similar transfers could have been made from the other hosts if time and facilities had permitted their study. Evidently plants which grow over winter after autumn seeding are more likely to become infected than fast growing annuals seeded in the spring. This is probably due to the increased opportunity for nematode invasion because of the prolonged seedling stage and wet surroundings of autumn planted seed.

CONTROL

There are two chief sources of nematode infection of teasel plants and both are the result of contamination. These two sources are nematodes on the seed used for planting and nematodes remaining in the soil after



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CONTROL

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FIG. 4.—Same as FIG. 3 except the heads are cut open. Note the healthy pith in the normal head and discoloration in the infected head.

FIG. 5.—Infected teasel leaf. Note discolored areas along midrib.

an infected teasel or other host crop or weed has grown on the field. Control is a matter of eliminating these nematodes, as follows:

1. Teasel seed should be treated in hot water at 122°F. for one hour, or 120°F. for two hours in order to obtain a complete nematode kill. Experiments used in establishing these treatments included the use of formaldehyde solution and a wetting agent (Vatsol O.S.) in the treating bath, as these materials had previously increased the nematode killing power of this bath as used for narcissus bulbs. The germination of teasel seed exposed to these treatments is given in Table 3. In addition to the germination tests, the treated seed was planted in the field and readings were later taken on the early growth, mid-season growth, final stand, and condition of mature teasel heads and spines.

An examination of the above data together with that of criteria mentioned earlier indicated that:

a. Formaldehyde solution used in the treating water is harmful to the germination of teasel seed and also to the later growth of the plants.

b. Vatsol O.S. used in the treating water exerts little influence on the germination of teasel seed or the later growth of the plants.

c. Teasel seed may be treated at 122°F. for one hour or 120°F. for two hours in water with or without Vatsol. Such treatments reduce the seed germination, however, so that twice as much treated seed must be planted in order to secure normal field stands of teasels. Fortunately this is an unimportant factor, due to the abundance of seed produced by this crop. Teasel plants resulting from treated seed showed increased mid-season growth, more vigorous and upright mature plants with increased number of heads and normal stiffness of spines.

2. Soil can be freed of *D. dipsaci* by rotation with crops which are not host plants, provided it is kept free of weeds, especially in wet seasons.

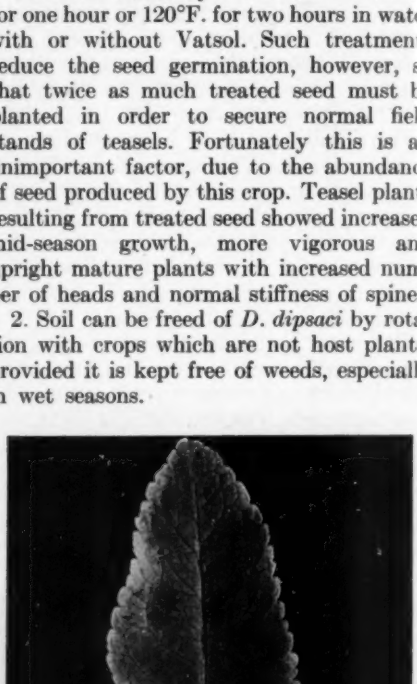

FIG. 6.—Normal teasel leaf.

Nematode infection of teasel plantings became nearly non-existent as a result of planting hot-water-treated teasel seed on properly managed soil. Fields known to be infested were plowed or disked in the autumn to destroy all growing plants and seeded the following spring to fast growing annuals to be harvested or used as a cover crop. After a 3-year period these fields were relatively free of nematode infestation, providing the residue from the former teasel crop had been properly destroyed.

SUMMARY

The nematode *Ditylenchus dipsaci* has been recorded as doing extensive damage to teasel crops in the Pacific Northwest, when proper control measures were not used.

Infected teasel plants may be dwarfed in appearance, having leaves with discolored areas along their midribs, later dying. The crown is often discolored and may be rotted to various degrees. Top growth from such crowns may be of normal size, but bear misshapen heads or burs, known as puff balls. In severe cases no top growth is produced.

In a series of tests made, plants which became heavily infected with bulb and stem nematodes from teasels, were large flowered collomia, oats (winter and spring types), rye, and wheat (winter and spring types). Buckhorn plantain and red clover plants contained a few nematodes, which were unable to reproduce. Corn, crimson clover, Hubam clover and field peas failed to become infected.

Control consists of eliminating the two main sources of infection, namely, the nematodes remaining in the soil after an infected crop has been harvested and those with the seed. Nematodes are eliminated from the soil by rotation with resistant crops, special attention being given to weed control, and from the seed by treatment with hot water.

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(2) KÜHN, JULIUS. *Über das Vorkommen von Anguillulen in erkrankten Blütenköpfen von* Dipsacus fullonum L. Zeitschr. Wiss. Zool. **9** (1): 129–137. 1857.

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NEW MEMBERS OF THE ACADEMY

There follows a list of persons elected to membership in the Academy, by vote of its Board of Managers, since April 1, 1950, who have since qualified as members in accordance with the bylaws (see also this JOURNAL **40**: 302–306, 1950).

RESIDENT

Elected April 17, 1950

Chan-Mou Tchen, physicist, National Bureau of Standards, in recognition of his contributions to the theory of fluid mechanics, especially the application of statistical methods to motion of small particles and chain molecules, and the treatment of flow problems involving heat addition.

Elected June 18, 1951

Francis C. Breckenridge, physicist, National Bureau of Standards, in recognition of his contributions to aviation lighting and signal colors, and in particular for the evaluation of approach light systems, the development of a chromaticity diagram and the coordination of signal colors, and for his productive work with the I.E.S. and the I.C.I. in these fields.

Newbern Smith, Central Radio Propagation Laboratory, National Bureau of Standards, in recognition of his contributions to studies of radio propagation and the ionosphere, and their application to problems of radio communication.

Elected November 19, 1951

Ernest N. Cory, assistant director, Extension Service; head, Department of Entomology; and State entomologist, University of Maryland, in recognition of his contributions to entomology, in directing research, teaching, and regulatory work of the Department of Entomology at the University of Maryland since 1914; having an important part in the growth of the American Association of Economic Entomologists; having managed the Journal of Economic Entomology with a world-wide distribution; having published approximately 200 scientific articles on a wide variety of insects, and having initiated and directed the published works of many associates.

George McMillan Darrow, pomologist, U. S. Department of Agriculture, in recognition of his outstanding contributions to plant breeding and genetics, particularly with respect to the utilization and interpretation of polyploidy in plants.

Carlton M. Herman, game pathologist, Fish and Wildlife Service, U. S. Department of the Interior, in recognition of his contributions to knowledge of parasites of birds and mammals, including bird malaria, and the epidemiology of diseases of wildlife.

Michael J. Pelczar, associate professor, Department of Bacteriology, University of Maryland, in recognition of his research work performed in the field of bacterial physiology and metabolism.

John H. Zeller, in charge of swine investigations, Bureau of Animal Industry, in recognition of his contributions to the science of swine production.

Elected December 17, 1951

Richard S. Hunter, optical engineer, Henry A. Gardner Laboratory, in recognition of his contributions to tristimulus photoelectric colorimetry, to the analysis of gloss and its measurement, to the design of apparatus for testing appearance properties of materials.

Philip R. Karr, physicist, National Bureau of Standards, in recognition of his studies of radiation fields and of the penetration and diffusion of X-rays through barriers.

Kathryn Knowlton, biochemist, National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, in recognition of her contributions in research and development of analytical methods for metabolic research.

Louis R. Maxwell, physicist, Naval Ordnance Laboratory, in recognition of his studies on average lifetime in excited states (atomic), electron diffraction of gases and liquids, and magnetic investigations of antiferromagnetic materials.

Norman B. McCullough, chief, Laboratory of Clinical Investigations, National Microbiological Institute, National Institutes of Health, in recognition of his many outstanding contributions to our knowledge of the cause, diagnosis and treatment of brucellosis in man.

Sherman Ross, associate professor of psychology, University of Maryland, in recognition of his contributions to the science of psychology, and in particular his researches on the effects of diet on social behavior.

James A. Shannon, associate director, National Heart Institute, National Institutes of Health, in recognition of his outstanding research particularly in areas of the physiology of excretion and of the pharmacology and chemotherapy of antimalarial drugs.

Falconer Smith, scientist, U. S. Public Health Service, in recognition of his work on radiation sickness.

Lawrence Zeleny, chief, Standardization Research and Testing Division, U. S. Department of Agriculture, in recognition of his work in the chemistry of fats and oils and cereal chemistry.

Elected January 14, 1952

Edith K. Cash, mycologist, Division of Mycology and Disease Survey, U. S. Department of Agriculture, in recognition of her contributions to mycology and in particular her researches on the taxonomy of the Discomycetes.

Raymond N. Doetsch, assistant professor of bacteriology, University of Maryland, in recognition of his contributions to general bacteriology with particular emphasis on physiology and dairy bacteriology.

Anna Hietanen-Makela, chief, Petrological Investigations Unit, U. S. Geological Survey, in recognition of her contributions to metamorphism and structural petrology.

Alice Phillips Withrow, plant physiologist, Smithsonian Institution, in recognition of her contributions to radiation physiology.

Robert B. Withrow, chief, Division of Radiation and Organisms, Smithsonian Institution, in recognition of his contributions to radiation physiology.

Elected February 18, 1952

Clifford Evans, associate curator of ethnology, U. S. National Museum, in recognition of his contributions to South American archeology, especially the Amazon region.

Thomas J. Killian, science director, Office of Naval Research, in recognition of his contributions to the science of physics, particularly his research on electrical discharges in gases, and his outstanding contributions as an administrator of Navy sponsored basic research.

E. R. Piore, deputy chief and chief scientist, Office of Naval Research, in recognition of his contributions to the science of physics, particularly his work on electron emission, and his outstanding services in the encouragement and administration of basic research.

Elected March 17, 1952

L. B. Aldrich, director, Astrophysical Observatory, Smithsonian Institution, in recognition of his ability and accomplishments both as an investigator in astrophysics and as administrator of the Astrophysical Observatory.

Howard L. Andrews, chief, section on Nuclear Radiation Biology, National Institutes of Health, in recognition of his achievements in research on and the teaching of nuclear radiation phenomena in relation to public health and civil defense.

M. Thomas Bartram, chief, Bacteriological Branch, Division of Microbiology, U. S. Food and Drug Administration, in recognition of his work on the bacteriology of foods.

E. P. Cronkite, head, Hematology Division, Naval Medical Research Institute, in recognition of his contributions in use of blood derivatives in clinical medicine, hematologic effects of radiation, hemostasis in normal and irradiated animals, and hematologic and lethal effects of atomic bomb radiation (Bikini and Eniwetok).

R. Harold Draeger, head, Atomic Medical Division, Naval Medical Research Institute, in recognition of his work in the field of atomic medicine, particularly the biological engineering of equipment for the exposure of animals to atomic bomb air blast, thermal and ionizing radiation.

William H. Hoover, chief astrophysicist, Astrophysical Observatory, Smithsonian Institution, in recognition of his ability as a research investigator in physics, astrophysics, and plant physiology.

Richard H. Lee, commander, Allied Science Section of the Medical Service Corps, U. S. Navy, in recognition of his research in night vision and biological aspects of the testing of atomic weapons.

Hui-Lin Li, visiting research scientist, U. S. Department of State, in recognition of his contributions to the botany of Chinese plants, especially his studies of the Scrophulariaceae and of the flora of Formosa.

William D. Reed, entomologist, Department of the Army, Office of the Chief of Engineers, in recognition of his services to the science of entomology in research and administration.

Glenn G. Slocum, chief, Division of Microbiology, Food and Drug Administration, in recognition of his work on the microbiology of foods and drugs.

Elected April 7, 1952

Ralph A. Alpher, physicist, Johns Hopkins University Applied Physics Laboratory, in recognition of his contributions to astrophysics, particularly his contributions to theories of the origin of the elements, as well as other work in fluid mechanics and cosmic rays.

Harold J. Coolidge, executive director, Pacific Science Board, National Research Council, in recognition of his researches in mammalogy and his outstanding work in organizing and directing various scientific expeditions and promoting international conservation of wildlife and world extension of national parks and primitive areas; especially for his work in extending international cooperation in Pacific science.

Alden H. Emery, executive secretary, American Chemical Society, in recognition of his contributions to the knowledge of sources of rock strata gases, sources and collection of dust in mines, mineragraphic identification of minerals; microscopic mineralogy, treatment and utilization of nonmetallic minerals, and mineral fillers.

Robert C. Herman, physicist, Johns Hopkins University Applied Physics Laboratory, in recognition of his contributions to molecular physics, solid state physics, and astrophysics, and in particular his work in molecular dynamics, luminescence and photoconductivity, and the origin of the elements.

NONRESIDENT

Elected November 19, 1951

O. Wilford Olsen, head, Department of Zoology, Colorado Agricultural and Mechanical College,

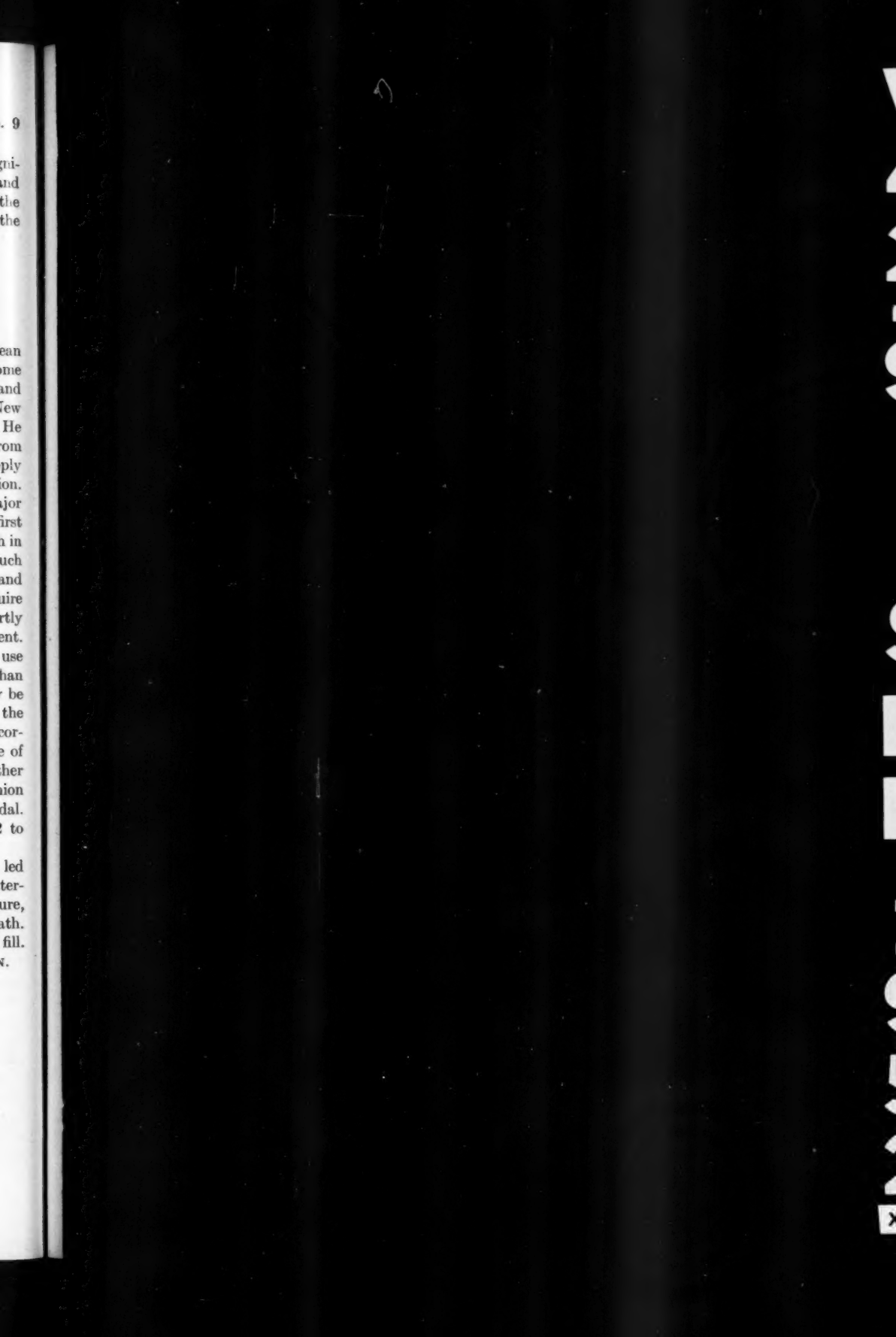
Fort Collins, Colo., in recognition of his investigations on control and therapeutics of parasites of cattle, particularly liver flukes, and parasites of wildlife.

Robert L. Weintraub, supervisory plant physiologist, Camp Detrick, Maryland, in recognition of his research in plant physiology and chemistry, particularly his contributions to the knowledge of plant growth substances and the effect of radiant energy on plants.

Obituary

JAMES LEE PETERS, curator of birds at the Museum of Comparative Zoology, Harvard University, died in Boston in his 62d year on April 19, 1952, after a rather sudden heart attack complicated by pneumonia. Aside from field trips to various parts of North and South America and to Europe, his entire life was spent in the Boston region, where he was born on August 13, 1889, and his whole scientific career, save for a short service in the field with the old Biological Survey of the Department of Agriculture, was centered in the great museum at Harvard. Following his graduation from Harvard in 1912 he worked without title or salary for a number of years as assistant to the late Outram Bangs, later becoming assistant curator and, on the death of Bangs in 1932, curator of the division of birds.

In the early years of his work at the museum Peters made numerous expeditions, beginning with a trip to Quintana Roo in 1912. Four years later he collected in the northern part of the Dominican Republic. He served with the U. S. Army in France in the first World War, but after the armistice resumed bird work. In 1920 and 1921 he was in Argentina, and particularly in Patagonia, making special observations on the ducks for the late John C. Phillips, but obtained a general collection of the avifauna of the region as well. In 1922 he spent some time on the island of Anguilla, West Indies, and late in 1927 he made the first ornithological survey of the Corn Islands, off the coast of Honduras. From these islands early in 1928 he went to the Caribbean lowlands of Honduras, where he collected for some three months. This was his last field trip, and while his personal collecting was confined to New World birds, his studies were world-wide. He wrote technical reports on other collections from Asia, Africa, and New Guinea and became deeply interested in nomenclature and classification. This provided the background for his major work, his *Check list of birds of the world*, the first volume of which appeared in 1931, the seventh in 1951. At the time of his death he had much manuscript prepared for the eighth volume and anticipated that the total work would require about 15 volumes. This great work, only partly accomplished, will long remain his monument. Few recent publications are in more constant use by systematic ornithologists the world over than these books, and it is hoped that a way may be found to have the task completed. In 1934 the German Ornithological Society made him a corresponding member because of the excellence of this work, and six years later he was further recognized by the American Ornithologists' Union with their highest award, the Brewster Medal. He was president of this society from 1942 to 1945.

His interest in questions of nomenclature led him eventually to the presidency of the International Commission of Zoological Nomenclature, which position he held at the time of his death. His passing leaves a gap it will be difficult to fill.

HERBERT FRIEDMANN.